The Cultural Eutrophication of Koontz Lake Indiana

* Causes
* Consequences
* Correction

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PREFACE

This report is the first such "feasibility study" granted by the new Lake Enhancement Program which became funded beginning in mid-1987. This report is sectioned into 1: the Lake; 2: the Watershed; and 3: Summary/Recommendations, Conclusions. The programming plan that was proposed has a high emphasis on data from Koontz Lake. Valuable impressions regarding the watershed and its relationship with the Lake have been discussed wherever possible within the scope of this proposal. Other agencies have been undertaking concurrent work in the Pontius Ditch and elsewhere in the watershed. Many fine efforts are underway by individuals, agencies, and consultants.

The writers of this report are excited and proud to present this comprehensive study with high quality data and interpretation for the improvement of Koontz Lake, and as a momentous contribution to the Indiana Lake Enhancement Program.

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EXECUTIVE SUMMARY

Koontz Lake (Starke-Marshall Cos. IN) is a eutrophic lake composed of three basins. Physical, chemical and biological data indicate that water quality has remained relatively unchanged since at least 1965. The lake experiences problem growths of aquatic weeds during summer as well as frequent blue-green algal blooms. The sport fish community of the lake appears to have degraded in recent years, and the east basin is infilling with sediment delivered via Pontius Ditch. The current project examines the current status of the lake, historical trends in water quality and land use practices, and identifies significant factors determining water quality.

Prior to the mid 1930´s, the dominant factor contributing nutrients to Koontz Lake was septic tank effluent from shoreline residences. Connection of Pontius Ditch to the east basin of the lake during the mid 1930´s resulted in a pronounced increase in the delivery of both nutrients and inorganic sediments to the lake. Pontius Ditch is the prime factor responsible for the eutrophication of Koontz Lake and its influence appears to have increased markedly in recent years as evidenced by the formation of a sediment delta at its mouth in the last 33 years and a marked increase in carbonate content of lake water and associated increase in aquatic weed problems since 1965. The aquatic weed problem has also worsened as a result of habitat expansion throughout Koontz Lake associated with nearshore erosion (0-5 feet water) and subsequent shoaling of offshore (5-10 feet water) areas from redeposited sediment. Aquatic weeds, especially near the Pontius Ditch delta in the east basin, appear to trap stream borne nutrients and thus are largely responsible for minimizing algal blooms in Koontz Lake.

Recommendations for enhancing water quality in Koontz Lake include:

1. Leaving the vegetation on and near the Pontius Ditch delta intact to serve as an in-lake nutrient and sediment trap.

2. Prohibiting large scale dredging in the east basin. Small scale cosmetic dredging for navigation may be permitted.

3. Limiting speed boats to open water areas of the central basin. Waves generated by boats are likely responsible for nearshore erosion and the offshore shoaling that is expanding aquatic weed habitat.

4. Prohibiting large-scale radical removal of aquatic weeds with chemicals. The system will likely shift quickly to problem blue-green algae and deteriorates water quality. Small scale chemical treatment of weeds as currently done actually promotes colonization by beneficial pondweeds.

5. Encouraging lake residents to cease lawn fertilization and removal of emergent aquatic weeds in nearshore areas and to maintain septic tanks, drain fields, and seawalls.

Opportunities exist in the Pontius Ditch watershed for land treatment of the nutrient and sediment loading problem demonstrated in the study of the lake. The watershed study targeted the Pontius Ditch since it is the largest contributor of water to Koontz Lake. The watershed study method included: 1) Land Use Overview; 2) Highly Erodible Land (HEL) Study; 3) Slope/Topography Study; and the resulting 4) Target Sites for Constructed Solutions. Study resources included comparisons of 1957 and 1972 aerial photographs; USGS topography; Marshall County Soil Survey; and numerous site visits throughout the watershed.

The actions recommended for watershed management that are suggested in the Watershed portion of the study include: preservation of remaining upland depressions; recommended monitoring several stations in the Pontius Ditch for nutrients and sediments; further study and possible implementation of several in-stream constructed nutrient/sediment traps (see map); removal of HEL from crop production (see map); monitor other current and future sources of soil and water pollution including the town of Koontz Lake; preserve additional natural areas that buffer the lake from surrounding upland areas; encourage additional minimum and no-till farm practices, animal waste handling practices, and proper location of animal operations; and recommend the use of constructed wetlands to provide nutrient removal that is not achieved by conventional sediment traps.

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ABSTRACT

The current study at Koontz Lake was designed to: 1. assess current water quality, 2. determine historical changes in water quality and watershed land use practices, 3. identify the factor(s) that are controlling water quality, and 4. make recommendations for enhancing water quality and lessening the impact of watershed related practices. Koontz Lake currently is considered eutrophic and experiences midsummer problems with hypolimnetic anoxia (>10 feet), excessive aquatic macrophyte growth, and frequent blue-green algal blooms. Complaints regarding the quality of the sport fish populations are often heard from residents.

Records for most water quality parameters are post 1964. A total of 21 investigations were conducted by the State during this period. The physical and chemical data suggest that water quality has not changed markedly since at least 1965. Lake water alkalinity increased progressively for the period 1965-1975 and remained relatively unchanged since suggesting a marked change in carbonate delivery from the watershed for the period.

Major bacterial contamination of Koontz Lake from improperly treated human wastes and possibly animal wastes was evident during the 1950's and 1960's, but the situation was corrected by 1971. Since at least 1975 blue-green algae have dominated the algal assemblages the lake and they periodically develop excessive "blooms" during mid summer.

Aquatic weeds were first documented as a potential management problem by the DNR in 1965. The overall extent of the weed infestation increased progressively throughout the late 1960's and early 1970's so that by 1974, the DNR considered all areas of the lake < 8 feet to be seriously infested with aquatic weeds and suggested implementation of an aquatic weed control program. Currently, the problem is most severe in the east basin and is caused principally by coontail. Chemical treatment of selected portions of this basin during 1988 greatly reduced coontail and encouraged dominance by beneficial species of pondweed. In addition to being positively associated with increasing delivery of nutrients and carbonates from the watershed, expansion of weeds throughout the lake in the past 33 years is likely a reflection of increasing habitat resulting from nearshore erosion and subsequent offshore redeposition to shoal areas to within the photic zone.

While the DNR considered bluegill and largemouth bass populations in Koontz Lake during 1955 to be good to excellent, their 1965 survey indicated that the fishing had deteriorated to a point where it was considered of little value to anglers. Subsequent degradation prompted the DNR in

1969 to propose a total fishery renovation for the lake. This took place in 1970-71, and by 1973 gamefish comprised 73% of total fish abundance. This increased to 87% in 1983. Unfortunately, the fitness of the gamefish populations has not increased as has abundance. This has been attributed both to expansion of aquatic weeds to problem proportions after 1965 as well as to generally low predator fish numbers. To address the latter, DNR stocked northern pike in the 1970's and imposed a 14-inch size limit on largemouth bass in 1984.

Our bathymetric map and sediment core studies clearly demonstrate that the Pontius Ditch is largely responsible for the eutrophication of Koontz Lake. Connection of Pontius Ditch to the east basin of the lake during the mid 1930's resulted in a pronounced increase in the delivery of both nutrients and inorganic sediments to the lake. The influence of this ditch on Koontz Lake appears to have intensified since at least 1955. During the past 33 years, the ditch has build a major sediment delta at its mouth that has become colonized by emergent macrophytes. Sediment from this stream source has also filled in all deep areas of the east basin. As mentioned previously, the alkalinity of lake water has increased markedly since 1965 with increased delivery of watershed derived carbonates via Pontius Ditch being the likely source. Changes in chemical delivery to the lake is likely to have been one of two major factors responsible for the progressive increase in the severity of weed problems since 1965. The second factor responsible for increased weed extent is the plant habitat expansion throughout Koontz Lake associated with nearshore erosion (0-5 feet water) and subsequent shoaling of offshore (5-10 feet water) areas from redeposited sediment. Such shoaling has increased the area of the lake that lies within the photic zone (Secchi= 5 feet) and thus available for macrophyte colonization.

The delta at the mouth of the Pontius Ditch is currently stabilized by rich emergent and submergent macrophyte growth. At present, it is functioning as an in-lake biotic filter for both inorganic and nutrients being delivered by Pontius Ditch. It should be left intact as should a broad zone of coontail immediately in front of it. (Large scale dredging will only resuspend nutrient rich sediments into the watercolum, destabilize the delta, and promote further eutrophication of the lake.) A degree of small scale dredging to facilitate navigation from properties trapped by the delta should be considered on an individual case basis.

Eutrophication of a lake promotes excessive growth of either algae or weeds but not both. Currently Koontz Lake is dominated by weeds, but radical chemical treatment of weed beds will cause a fast release of nutrients and rapid uptake by algae will follow. Such a proliferation of algal populations will promote shading and death of weed beds, and the major management problem in the lake will shift to the more ominous algae. Once that happens, lake management costs will skyrocket, and the chance of success will diminish. Small scale chemical treatment as practiced in the east basin during 1988 successfully reduced coontail and promoted expanded growth of the beneficial pondweed species. Such small scale chemical control practices should be permitted in the future after reviewing specific details of proposed control operations.

As we have demonstrated previously at Lake Maxinkuckee, intense speed boat activity resuspends sediments and greatly increases water turbidity. At Koontz Lake, the effects of this activity appears to have been maximized and has led to a pronounced movement of sediment within the lake. Between 1955 and 1988 the 0-5 foot water depth contour in all three basins doubled in extent, while a corresponding decrease in the 5-10 foot contour was noted in both the west and central basins. The contraction of the same contour in the east basin was approximately 86% and was also influenced by the buildup of the Pontius Ditch delta. Such erosion of nearshore areas and associated shoaling of deeper areas by redeposited sediment in basins not receiving the brunt of stream delivered sediment is likely the direct result of excessive wave activity generated by motor boats. It is recommended that all speed boat activity should be eliminated from the west and east basins of Koontz Lake. These basins are too small to adequately absorb boat generated waves before they promote sediment resuspension. Even within the central basin, fast boating and skiing should be restricted to a distance of > 200-400 feet from shore to minimize wave action. Shoreline residents should be encouraged to leave beds of emergent grasses and sedges in nearshore areas intact. These act as an efficient natural buffer against wave action. Finally, some consideration should be given to finding ways to establish an upper limit on the number of boats permitted to operate simultaneously on the lake.

The predator enhancement work conducted by the DNR should improve sport fish populations in time. The success of northern pike introductions has been good, and the 14-inch size limit placed on largemouth bass should be continued until such time that the gamefish fitness improves markedly.

There are a number of actions that individual residents can do to enhance water quality in the lake. Lawn fertilization should be curtailed especially at shoreline residences. Lawn irrigation with lake water will provide more than sufficient nutrients for green lawns. Special care should be taken to insure that septic tanks and drain fields are operating properly and not adding excessively to the nutrient pool of the lake. Finally, residents should try to buy household products that are low in phosphates thereby reducing potential loading of nutrients into the lake via the septic system.

Opportunities exist in the Pontius Ditch watershed for land treatment of the nutrient and sediment loading problem demonstrated in the study of the lake. The watershed study targeted the Pontius Ditch since it is the largest contributor of water to Koontz Lake. The watershed study method included: 1) Land Use Overview; 2) Highly Erodible Land (HEL) Study; 3) Slope/Topography Study; and the resulting 4) Target Sites for Constructed Solutions. Study resources included comparisons of 1957 and 1972 aerial photographs; USGS topography; Marshall County Soil Survey; and numerous site visits throughout the watershed.

The actions recommended for watershed management that are suggested in the Watershed portion of the study include: preservation of remaining upland depressions; recommended monitoring several stations in the Pontius Ditch for nutrients and sediments; further study and possible implementation of several in-stream constructed nutrient/sediment traps (see map); removal of HEL from crop production (see map); monitor other current and future sources of soil and water pollution including the town of Koontz Lake; preserve additional natural areas that buffer the lake from surrounding upland areas; encourage additional minimum and no-till farm practices, animal waste handling practices, and proper location of animal operations; and recommend the use of constructed wetlands to provide nutrient removal that is not achieved by conventional sediment traps.

1: the Lake.

Introduction

Prior to 1848, the area currently encompassing Koontz Lake consisted of two shallow, non-connected kettle lakes that were formed during the last glaciation. Woodsworth Lake occupied the deeper portions of what today are the central and western basins of Koontz Lake. A smaller unnamed lake occupied the current eastern basin of Koontz Lake and lacked any connection to the larger Woodsworth Lake.

Koontz Lake was created in 1848 when an earthen dam was constructed for a grist mill at the western end of Woodsworth Lake. Water level was raised such that the two lakes were joined and the newly Koontz Lake attained its current shoreline and depth configuration. Structural failures necessitated the reconstruction of the dam in 1852, 1858 and 1860. The present control structure was put in place in 1978.

Koontz Lake has a surface area of approximately .52 mi^2 and a watershed of 5.9 mi^2. Although two inflows contribute to the lake, by far the largest contribution is from the Lawrence Pontius Ditch which drains 4.4 mi^2 of the watershed and enters the lake along the southern shore of the eastern basin.

The current chapter is designed to define the current water quality of Koontz Lake and to determine whether current values represent a marked decline in water quality within the historical past. Accordingly, it has been separated into three subsections. The first section presents a detailed examination of the historical database on the water quality for Koontz Lake. The second section summarizes the water quality analyses conducted as part of the present study and compares values to earlier studies. The third and final section details our sediment studies at Koontz Lake where we were interested in learning the extent of basin infilling in the historical past as well as changes in phosphorus loading to the lake. Management implications of our analysis of past and current water quality will be discussed later in this report.

Historical Water Quality

Database

A total of 21 separate studies were conducted at Koontz Lake between 1964 and 1986 for which data were available (Table 1). The Indiana Department of Natural Resources surveyed the fish community 13 times during this period and in several of these surveys included data on water chemistry

Table 1. Chronology of Investigations at Koontz Lake

1964	Indiana State Board of Health. Bacteriological investigation two times during summer for 38 sampling stations.
1965	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1965	Indiana State Board of Health. Bacteriological investigation at 25 stations.
1966	Indiana State Board of Health. Bacteriological investigation two times during summer for 127 stations.
1967	Indiana State Board of Health. Bacteriological investigation at 36 stations.
1968	Indiana State Board of Health. Bacteriological investigation at 37 stations.
1969	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1971	Indiana State Board of Health. Bacteriological investigation at 38 stations.
1971	Indiana Department of Natural Resources. Survey of fish community.
1972	Indiana Department of Natural Resources. Survey of fish community.
1973	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1974	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters.
1975	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters.
1975	Indiana State Board of Health. Survey of several physical/chemical parameters and algal abundance and composition for construction of BonHomme eutrophication index.

Table 1. (cont'd)

1977	Indiana Department of Natural Resources. Survey of fish community, macrophyte composition.
1978	Indiana State Board of Health. Bacteriological investigation at 2 stations.
1979	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters.
1983	Indiana Department of Natural Resources. Survey of fish community, physical/chemical parameters, macrophyte composition.
1984	Indiana Department of Natural Resources. Population analysis of largemouth bass.
1985	Indiana Department of Natural Resources. Population analysis of largemouth bass.
1986	Indiana Department of Natural Resources. Population analysis of largemouth bass.

and macrophytes. The Indiana State Board of Health estimated bacterial numbers in the lake 7 times and visited the lake once in the mid-1970's to collect water chemistry and select biological data for construction of a eutrophication index for classifying the lake relative to other lakes in the state. No other data were found in the files of state and federal agencies or as research projects conducted by universities of the state.

Physical/Chemical Parameters

A total of thirteen physical and chemical parameters have been measured at Koontz Lake at a frequent enough interval to be useful in delineating historical trends (Table 2). Secchi depth transparency is a good estimator of either inorganic turbidity from suspended sediment or algal biomass. As secchi values have historically been recorded during summer, it is likely that they reflect algal biomass rather than suspended inorganic sediment. It is expected that secchi values should get progressively lower throughout summer as algal biomass builds in response to steadily increasing temperature. Thus, it is only valid to make interyear comparisons for individual months. June water clarity as measured by secchi readings were greatest in 1988, but no clear historical trend is apparent in the data for the period 1965-1988. Likewise, both July and August values were greatest in 1988, and no historical trends were noted. As will discussed later in this report, it is felt that the greater water clarity observed in 1988 as compared to earlier years is a reflection of the extreme drought conditions of the latter year and a possible reduction in nutrient loading from inflow streams.

As with secchi disc transparency, mean water column dissolved oxygen values are expected to decrease throughout the summer in response to increasing temperature and algal production (Table 2). Values for June, July, and September 1988 are higher than readings for comparable months of previous years. It is felt that this does not reflect a long-term increase in water quality, but is a reflection of the extreme drought conditions of 1988 whereby algal production is likely to have been uncharacteristically low due to a reduction in the delivery of nutrients from the watershed.

A good measure of the extent of eutrophication is provided by the extent of water column anoxia in mid summer (Table 3). The historical data suggest that the water column of Koontz Lake during June normally is devoid of oxygen below a depth of 15-20 feet. In 1988, however, the central and west basins displayed no anoxia, and the east basin was devoid of oxygen below 17 feet. It is important to note that the west basin is so shallow that it is expected to remain

Table 2. Historical Changes in Physical and Chemical Parameters at Koontz Lake for the Period 1965-1988

		June 1965	June 1969	July 1973	July 1974	June 1975	August 1975	June 1979	July 1983	June 1988	July 1988	September 1988
Secchi	feet	5	3	3.5	3.5	3.5	3	4.5	3	6.54	4.22	4.55
Mean Dissolved Oxygen	mg/L	3.84	7.16	5.16	2.66		3.85	6.28	3.24	8.49	5.47	7.03
Alkalinity	mg/L as CaCO3	123	136	144	170		178	136	153			
pH		8.7	8.5	9	9		8	9	10			
Na	mg/L	5										
SO4	Mg/L	90	49									
Mn	mg/L	0.03	0.08									
Total Phosphorus	mg/L		0.1	0.03		0.05				0.034	0.09	0.057
Nitrate-N	mg/L			0.8								
Ammonia-Nitrogen	mg/L									0.046	0.108	0.097
Total Kjeldahl N	mg/L									1.08	1.62	0.44
Nitrite-Nitrate	mg/L									0.119	0.014	0.018
Chlorophyll	mg/m3									4.05	5.34	5.34

Table 3. Historical Records of Water Column Anoxia in Koontz Lake, IN

Observation	Initial Depth of <1 mg/L Dissolved Oxygen
June:	
1965	20 feet
1969	15 feet
1979	20 feet
July:	
1973	15 feet
1983	5 feet
August:	
1975	10 feet

oxygenated throughout the year due to its morphometry. July anoxia has been apparent historically below 5-15 feet. The 1988 data are in agreement with this trend whereby both the east and central basins were anoxic below 13 feet. During September 1988 only the east basin displayed anoxia, and this was initiated at a depth of 17 feet. It is likely that the lake had begun to destratify at the time, thus adding oxygen to the lower water column of the more wind exposed central basin.

Alkalinity, a measure of the carbonate buffering capacity of lakes, displayed the clearest historical trend of any physical or chemical parameter (Figure 1). From a low of 123 mg/L in 1965, values increased progressively during the next ten years to peak at 178 mg/L in 1975. Values declined slightly in subsequent years. The obvious source for the progressive increase in carbonate content of Koontz Lake water since 1965 is increased delivery from the watershed via soil erosion and leaching processes. It is highly unlikely that domestic sewage from the residences surrounding the lake had any appreciable impact on this parameter. As will be discussed later, alkalinity is but one of many parameters that record the accelerating impact of agricultural practices on water quality in Koontz Lake in recent years.

The remainder of the physical and chemical parameters were either sampled infrequently or failed to display a meaningful historical trend (Table 2). Total phosphorus, a good indicator of eutrophication, for summer 1988 were within the range of values recorded in earlier studies.

Microbiology

Mr David Singleton of the Starke County Health Department supplied microbiological data from 10 surveys conducted by the Indiana State Board of Health between 1964 and 1978 (Table 4). Although data were not available, Mr Duane Yazel of the Marshall County Health Department stated that the limited sampling of the lake since 1978 has failed to produce bacteria numbers that exceeded state standards. Please note that the early surveys were meant to identify pollution sources and thus were conducted in the vicinity of suspected violators. Had values been taken routinely at mid lake stations, the number of stations exceeding state standards would have been much lower.

Total coliform bacteria exceeded state standards routinely during the mid 1960's with improperly functioning septic tanks identified as the major contributor. It was noted in correspondence from the Indiana Board of Health to lake residents that it was also likely that high bacteria counts in the vicinity of the inlet of Pontius Ditch were

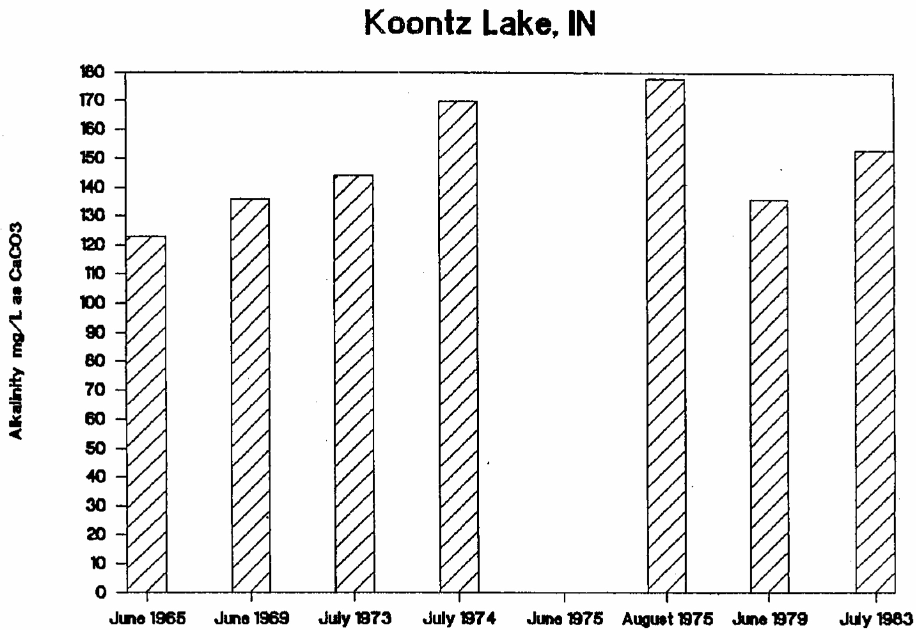


Figure 1. Koontz Lake Alkalinity for the Period 1965 - 1983

Table 4. Compilation of Past Microbiological Testing at Koontz Lake

Date	# Stations Sampled	Coliform Bacteria mpn/100mL Mean	Maximum	# Stations >1000/100 mL	Fecal Coliform mpn/100 mL Maximum	# Stations >400/100 mL	Fecal Strep/100 mL Maximum	# Station >100/mL
15 July 1964	12			10				
21 September 1964	26	612	8500	4				
29 July 1965	25	13593	43000	17				
6 July 1966	45	15654	93000	44			4300	2
30 August 1966	82	1192	23000	13			240	5
21 August 1967	36			3				
2 July 1968	37			2		1		
15 June 1971	38				70	0		
19 June 1978	1				0	0		
5 September 1978	1				170	0		

likely contributed by livestock in the watershed allowed to water in the ditch. By 1967 most of the septic sources had been corrected, and since 1971, no sampling stations have exceeded state standards for either total coliform or fecal coliform bacteria. The database for fecal strep is so limited that no conclusions can be reached. On the two occasions that it was measured in the summer of 1966 only five percent of the stations sampled exceeded state standards. Note that this was the time of maximum coliform bacterial contamination when 45% of stations exceeded state standards.

Phytoplankton

Phytoplankton samples have been collected only once as part of an Indiana Board of Health survey in the summer of 1975. Although representatives of three algal groups were identified, the lake was clearly dominated by blue-green algae (Table 5). Anabaena, Anacystis, Aphanizomenon, and Lyngbya, characteristic floral elements of eutrophic lakes, were the major genera encountered. These taxa are among the most common problem algae in North American lakes, and all have been observed to form floating scums on lakes especially during midsummer.

Macrophytes

The macrophyte (aquatic weed) community was examined three times during Indiana Department of Natural Resources fish surveys conducted between 1965 and 1983. The greatest diversity of taxa recorded has always been for the submergent community (Table 6). Several pondweed species were recorded and shared dominance with chara, water milfoil, and coontail. The remaining communities, emergents and floating-leaved, historically have been represented by only two taxa each. It is interesting to note that the species composition of the entire weed community appears to have changed little between 1965 and 1983.

As early as 1965 the DNR noted that large areas of the east basin were choked with weeds and that large open water areas witnessed algal blooms. The dominant plants at the time were chara, coontail, elodea and milfoil. The 1969 survey estimated that 12% of the surface area of the lake was covered with plants and suggested that the overall infestation by weeds was lower than that of 1965. This reduction was attributed to the fact that carp had increased during the period and increased water turbidity due to its feeding activity. Thus, the extent of weeds would have been reduced due to a reduction in light penetration into the water column.

Table 5. Phytoplankton Composition of Koontz Lake July 1975

Algal Group	Genus
Diatoms	Cyclotella
	Cymbella
	Fragilaria
	Synedra
Greens	Ankistrodesmus
	Chlorella
	Crucigenia
	Microspora
	Oocystis
Blue-Greens	Anabaena
	Anacystis
	Aphanizomenon
	Lyngbya
Dinoflagellates	Ceratium
	Dinobryon
	Peridinium

Table 6. Species Composition of the Macrophyte Community of Koontz Lake for the Period 1965-1983

Species	Common Name	1965	1969	1973	1977	1983
SUBMERGENTS:						
Ceratophyllum demersum	coontail	X	X	X	X	X
Chara spp.	chara	X	X	X	X	X
Elodea canadensis	elodea	X	X	X	X	X
Myriophyllum heterophyllum	water milfoil	X	X	X	X	X
Potomogeton crispus	curly pondweed	X	X	X	X	X
Potomogeton illinoensis	Illinois pondweed	X	X	X	X	X
Potomogeton pectinatus	sago pondweed	X	X	X	X	X
Potomogeton zosteriformis	flatstem pondweed	X	X	X	X	X
Utricularia vulgaris	bladderwort	X	X	X	X	X
Zannichellia palustris	horned pondweed	X	X	X	X	X
EMERGENTS:						
Scirpus spp.	bulrush	X	X	X	X	X
Typha latifolia	common cattail	X	X	X	X	X
FLOATING LEAVED:						
Nuphar advena	spatterdock	X	X	X	X	X
Nymphaea tuberosa	waterlily	X	X	X	X	X

By 1973, plant infestation had increased to 20% of lake surface area. This was attributed to the fact that the 1970 fisheries renovation had reduced rough fish resulting in a reduction in turbidity and an associated increase in light transmission into the water column. The 1974 survey noted that weeds were abundant in all areas of the lake <8 feet deep and that a chemical control program for the lake was needed. All later DNR surveys (1975-1983) mentioned that the weed community of the lake was dominated by chara and milfoil and that a weed control program was ongoing.

Fish

The Indiana Department of Natural Resources surveyed the fish community of Koontz Lake ten times between 1965 and 1983. In addition, detailed investigations of the largemouth bass population were conducted in 1984, 1985, and 1986.

A listing of the individual species caught and the contribution of each to total fish abundance caught during DNR surveys from 1965-1983 is presented in Table 7. Although a total of 26 taxa have been identified from Koontz Lake, bluegill, largemouth bass, pumpkinseed, and yellow perch are the dominant taxa present. Although numerically unimportant, northern pike have constituted over 30% of all fish weight caught in DNR surveys conducted after 1975 (Table 8). Bluegill is clearly the dominant panfish on a weight basis followed by redear sunfish. The remainder of the fish taxa have consistently contributed <10% of the total catch weight.

The 1965 DNR survey concluded that the fish community of Koontz Lake offered little for the angler and predicted that if the predator population continued to decline, the community would increase in overall abundance while being drastically stunted. The condition of the bass population was considered good, but that of bluegill was only average largely due to competition with pumpkinseed and gizzard shad. The best fish in the lake at the time was considered to be redear. Although data could not be found in DNR files, the 1965 report noted that the findings for the current year were in marked contrast to the findings of a survey ten years earlier that demonstrated good to excellent populations of bluegill and largemouth bass. It was felt that the community began to display a major degradation beginning in 1959 or 1960. By 1965, the DNR began to question the reproductive success of all gamefish species in the lake.

A further degradation of the fish community was noted during the 1969 survey. The condition of bluegill and redear was considered above average, while that of the remaining

Table 7. The Importance of Individual Fish Species Expressed as a Percent of Total Fish Abundance Caught During DNR Surveys at Koontz Lake

	1965	1969	1971	1972	1973	1974	1975	1979	1983
Black Bullhead	0.5							1.2	
Black Crappie	6.2	14.7	2.7	11.4	3	7	1.6	2.5	2.6
Bluegill	8.8	2.8	26.3	39.5	37.5	58.2	80.3	57.6	42.3
Bluntnose Minnow		0.2							
Bowfin	0.3	0.2							
Brown Bullhead		1.6			0.4	5.8	2.2	4.2	5
Carp	0.9	4							
Central Mudminnow			3.6	0.9					
Channel Catfish			5.4	0.9	0.8	1.9			
Emerald Shiner					1.1				
Golden Shiner	10.2	20.7				2.3		5.2	4.1
Grass Pickeral	0.9	0.1	0.9	0.9				0.1	
Green Sunfish	0.9	0.2						0.1	
Hybrid Sunfish	2.3								0.1
Lake Chubsucker	2.3	0.7							
Largemouth Bass	1.8	1.9	52.7	26.3	13.3	6.7	2.7	3.1	7.6
Northern Pike	0.3	0.1	0.9	2.6	9.1	5.6	1.1	2.1	2.3
Pumpkinseed	44.8	1.7		10.5	2.7	3	10.9	9.4	7.4
Redear	7.5	0.5				0.2		9.9	9.7
Spotted Gar	0.8	1.3							
Walleye						3.7		0.1	
Warmouth	1.6	0.3							
White Crappie		0.1							
White Sucker		0.1						0.1	
Yellow Bullhead	0.5	0.7			0.4	1.4		2	4.4
Yellow Perch	8.6	48.3	7.2	7	31.8	4.2	1.1	2.3	14.5

Table 8. The Importance of Individual Fish Species Expressed as a Percent of Total Fish Weight for DNR Surveys of Koontz Lake

	1975	1979	1983
Black Bullhead		2.3	
Black Crappie	1.2	1.4	2.3
Bluegill	26.2	21.8	8.9
Bluntnose Minnow			
Bowfin			
Brown Bullhead	7.1	7.6	10.5
Carp			
Central Mudminnow			
Channel Catfish			
Emerald Shiner			
Golden Shiner		2.8	2
Grass Pickeral		0.1	
Green Sunfish		0.1	
Hybrid Sunfish			0.1
Lake Chubsucker			
Largemouth Bass	19.2	7.2	6.3
Northern Pike	42.2	33.8	45.3
Pumpkinseed	3.6	4.3	1.9
Redear		12.6	13.5
Spotted Gar			
Walleye		1.2	
Warmouth			
White Crappie			
White Sucker		1.7	
Yellow Bullhead		2.3	5.1
Yellow Perch	0.4	0.1	4.2

taxa was ranked average or below. The carp population appeared to have doubled since 1965, and 76% of the fish in the lake were considered to be of no value to the angler. In addition, "black spot" was noted on several specimens of yellow perch. DNR staff recommended that the fisheries be completely renovated via rotenone following a slight drawdown of the lake to drive fish away from the vegetated fringes of the lake.

Although the earliest record of fish management at Koontz Lake appears to be the introduction of 500 northern pike in 1960, a full fish community renovation of the lake was undertaken by DNR in Fall 1970. Following rotenone treatment of the lake and its watershed streams, largemouth bass (13,455 including 455 adults), bluegill (4,600), redear (3,200), northern pike (3,500 fingerlings), channel catfish (2,000) and black crappie (720) were stocked. An additional stocking of 500,000 walleye took place on 11 May 1971.

By 1973, gamefish constituted 73% of the fish caught in the DNR survey, and the condition of all taxa was deamed average or above average. One negative note was that the yellow perch had not been completely destroyed during the renovation process as evidenced by the fact that 7% of the 1971 abundance of this species was made up of young of the year. Although recognizing that the Secchi depth had not changed markedly, the DNR suggested that water clarity was none the less better following renovation and attributed this to the fact that weeds had begun to increase in the lake because the turbidity of the water was reduced following elimination of carp. As will be seen later, this enhancement of weed populations was a mixed blessing. Finally, the DNR suggested that the lake currently supported too few predator fish and that this was likely to result in a reduction in the growth rate of bluegill and perch if not corrected. It was suggested that a 14" limit be put on largemouth bass.

Gamefish had increased to 83% of total fish by 1974, but it was noted that growth rates of the major species had declined from previous levels. It was suggested that this was attributable to an increase in the growth of aquatic weeds and an overharvest of the bass population. It was again suggested, as in 1973, that a 14" limit be placed on the largemouth bass population. Although it was felt that the fish community was generally improved since the renovation, it was somewhat disturbing that small die-offs of black crappie had been recorded during the spring of 1973 and 1974 that was attributed to bacterial infection. On a positive note, survey data confirmed that northern pike were reproducing in the lake.

By the time of the 1975 survey further evidence of a decline in the fitness of the fish community was presented. Although the total abundance of bluegill had continued to increase following renovation, that of the largemouth bass had been decline with a 50% reduction being noted between successive years. In addition, a drastic reduction in the growth, condition and maximum size of the bluegill population was noted. DNR staff suggested that the lake be treated with .8 ppb antimycin to thin the fish community abundance after which largemouth bass and pike fingerlings should be stocked at a rate of 100 and 50 fingerlings per acre, respectively. It was generally felt that the predator community of the lake had to be enhanced if the angler success was to be improved.

The Indiana Board of Health received a report of a massive fish kill at Koontz Lake on 3 June 1978. In addition, the DNR survey of 1979 documented that the growth rates of bluegill, crappie and bass were considered below average, while that of redear, perch and pike had actually increased since 1977 when over 87% of all fish caught were classified as gamefish. It appeared that while the gamefish population was expanding, its fitness was declining.

The same conclusion was reached following the 1983 survey. Although bass and perch numbers appeared to be increasing over values of previous years, the condition of all gamefish except redears was considered only average. A 14" limit was placed on largemouth bass on 1 October 1984, and the DNR performed detailed investigations of the bass population in 1984, 1985, 1986. By 1986, bass numbers were greater than recorded in 1984, and the population was dominated by small individuals. Thus, bass reproductive success appeared to be enhanced. The success of the 14" limit on gamefish populations must await the outcome of the next detailed fish community survey on the lake by DNR.

Changes in the percentage contribution of select species to total fish abundance as recorded in the DNR surveys of 1965-1983 are summarized in Figure 2. Bluegill, largemouth bass, and yellow perch were the overall greatest contributors to fish abundance for the period of study. Comprising <10% of fish abundance prior to fisheries renovation, the contribution of bluegill increased progressively in the post period to peak at >80% in 1975. Values in the latter two survey years, 1979 and 1983, have displayed a progressive decline from this peak level, but overall values have been three to eight times greater in the post than pre renovation periods.

Largemouth bass abundance contribution increased over ten-fold in the first two years following renovation, but declined progressively afterwards. Since 1975, values have been only double those of the pre period. Yellow perch, pumpkinseed, and black crappie appear to have been affected only slightly by the fisheries renovation, while the abundance contributions of both northern pike and brown bullhead appear to enhanced by the DNR management program. Finally, although generally feared during the prerenovation period, carp was never a major abundance contributor and was essentially eliminated in the post period.

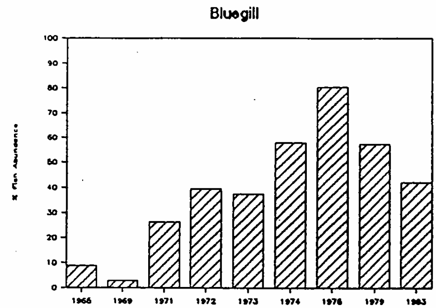
Another way of looking at the overall fitness of a fish community is to estimate the percentage of the population of each species that is considered large-bodied enough to be considered "catchable" by anglers (Figure 3). Although the abundance contribution of bluegill has continued to increase following fisheries renovation, the percentage considered catchable has remained lower than pre renovation values. On the other hand, the largemouth bass catchable percentage continued to increase throughout the early 1970's as the abundance percentage displayed a progressive decline for the same period. While catchable values were greatly reduced for largemouth bass immediately following renovation, by 1975 they had nearly approached the 1969 level. Thus, it appears that while renovation has resulted in increased abundance of small-bodied bluegills, the largemouth bass during the early 1970's was experiencing an overall reduction in abundance while being increasingly dominated by large-bodied individuals. The DNR instituted the 14" size limit on bass in 1984 in order to reverse this trend toward a reduction in predatory fish thereby hoping to increase predation on small-bodied bluegill and skew the population towards larger, better fit individuals.

Yellow perch catchability increased during the early 1970's but fell quickly to prerenovation levels after 1977. Data on black crappie and redear are rather sparse but suggest a slight increase in catchability following renovation. Finally, the progressive increase in the catchability of northern pike from 1972 to 1977 ending with a 100% catchability in the latter is a reflection of the stocking success (3,500 fingerlings) of this species in May 1971.

Current Water Quality

Introduction

Water quality parameters were collected during 1988 on 10 June, 10 July and 21 September. A single sampling station was established in each of the three basins (Figure 4). Stations were located in the area of deepest water as close to the center of each basin as possible. Dissolved oxygen and temperature profiles were determined with a YSI oxygen



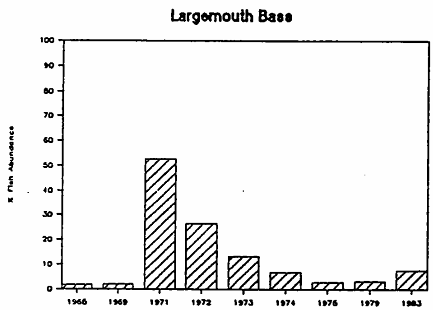


Figure 2. Changes in the Percentage Contribution of Select Species to Total Fish Abundance in Koontz Lake for the Period 1965 - 1983

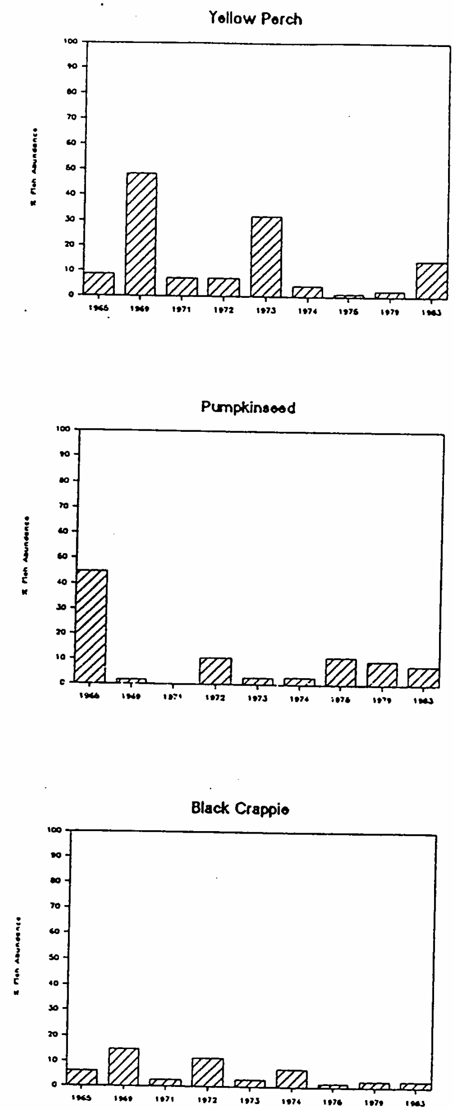


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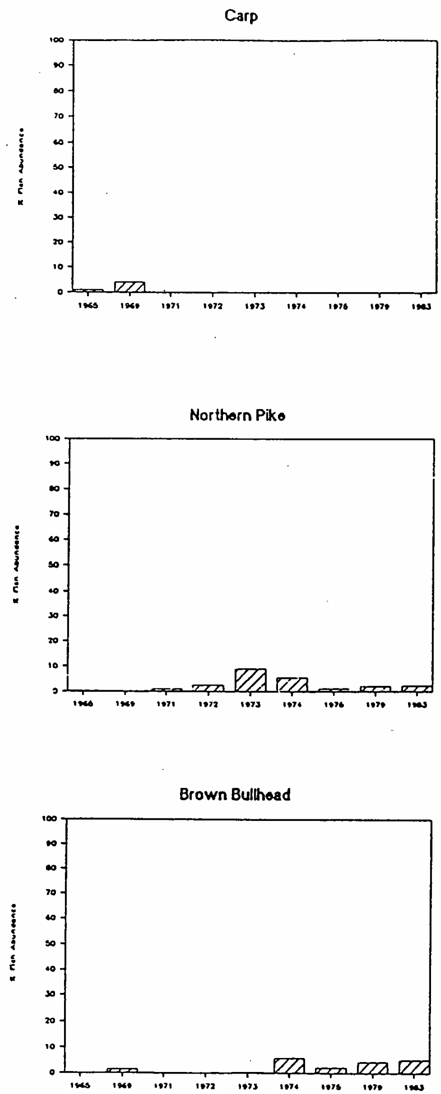
Figure 2. (cont'd)



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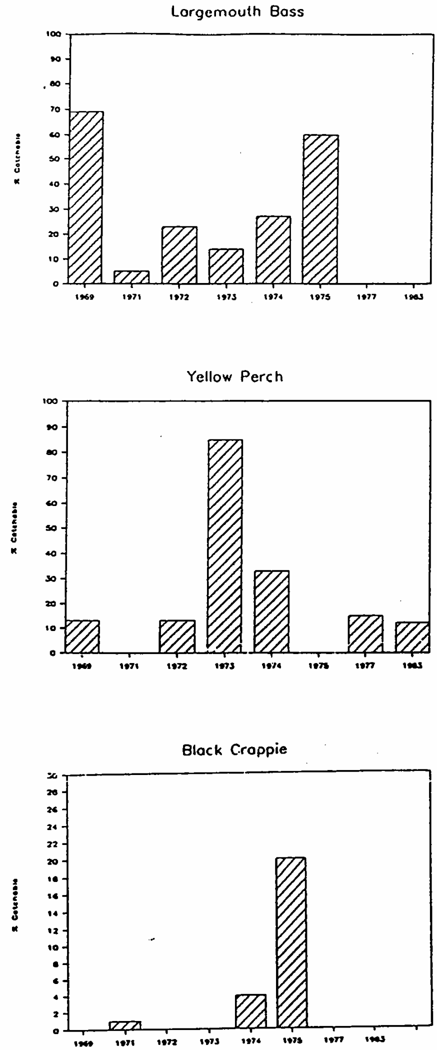


Figure 3. Changes in the Percent of the Population of Select Fish Species Considered to be of a Catchable Size

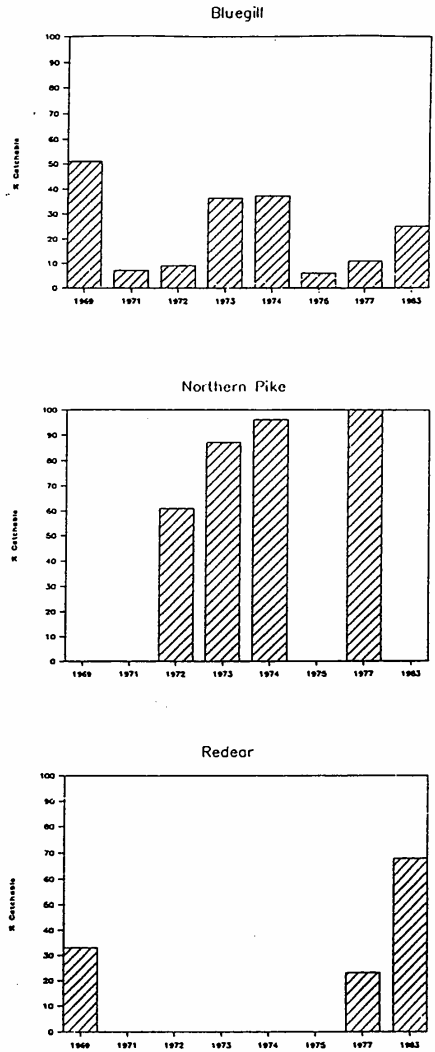


Figure 3. (cont'd)

Figure 4. Sampling Stations in the Three Basins of Koontz Lake Used for the Water Quality Survey

meter and light transmission was estimated with a Secchi disc and a Licor photometer. Water samples for chemical, bacteriological and chlorophyll analyses were taken from composite samples of the water column where a Kemmerer bottle was used to collect water at each meter of the water column. All analyses were performed in certified laboratories according to EPA techniques (EPA-600/14-79-020, Methods for Chemical Analysis of Water and Wastes, Revised March 1983). Data for physical and chemical parameters for individual basins during the 1988 survey are presented in Table 9.

Physical/Chemical Parameters

Temperature. Water column profiles clearly demonstrated that both the east and central basins were thermally stratified during June 1988 (Figure 5). The thermocline of the east basin was between two and three meters depth, while that of the central basin was between four and five meters. In marked contrast, the west basin was well mixed throughout its two meter water column. The July pattern was quite similar except that the thermocline of the east and central basins was higher in the water column, 2-3 meters and 3-4 meters, respectively (Figure 6). Again, the water column of the west basin was well mixed throughout. July water temperatures were the highest of the survey and reflected the unusually hot summer conditions witnessed in Indiana. Thermal stratification in both the east and central basins had broken down by the time of the September sampling, with the water columns of all three basins having cooled to a uniform 19-20 C (Figure 7).

Dissolved Oxygen. Midsummer oxygen values in the lower portion of the water column of lakes is governed by the degree of thermal stratification and the overall trophic state of the lake. The higher the trophic state (eutrophication) the greater the amount of organic matter falling to the bottom of the lake to decompose. If the lake is deep enough to stratify, oxygen is not replenished in the bottom layers readily and is consumed during the decomposition process. Thus, the higher the trophic state, the greater the likelihood that the lake becomes anoxic in the bottom of the water column (hypolimnion).

The lower portion of the water column (hypolimnion) of both the east and central basins displayed pronounced deoxygenation during June 1988 (Figure 8). As expected, the beginning of reduced oxygen corresponded to the bottom of the well mixed portion of the water column (epilimnion), the portion of the water column displaying the greatest temperature change per meter (thermocline). Thus, even early

OP
D.O
Plankton

Table 9. Values for Physical and Chemical Parameters for Individual Basins of Koontz Lake From the 1988 Survey

		June 1988			July 1988			September 1988		
		East	Central	West	East	Central	West	East	Central	West
Secchi	feet	4.91	10.37	4.33	3.45	5.16	4.04	5.08	4.33	4.25
Mean Dissolved Oxygen	mg/L	9.65	7.63	11.2	6.5	4.81	5.53	5.88	7.07	9.7
Ammonia	mg/L	0.063	0.051	0.026	0.124	0.124	0.076	0.111	0.153	0.028
Total Kjeldahl N	mg/L	1.24	0.85	1.16	1.35	1.47	2.05	0.4	0.42	0.51
Nitrite-Nitrate	mg/L	0.284	0.07	0.005	0.017	0.017	0.01	0.047	0.007	0.005
Total Phosphorus	mg/L	0.035	0.028	0.041	0.017	0.005	0.005	0.058	0.076	0.037
Chlorophyll	mg/m3	4.01	4	4	8.01	5.34	2.67	5.34	4.27	6.41

$\bar{x} = 0.034$

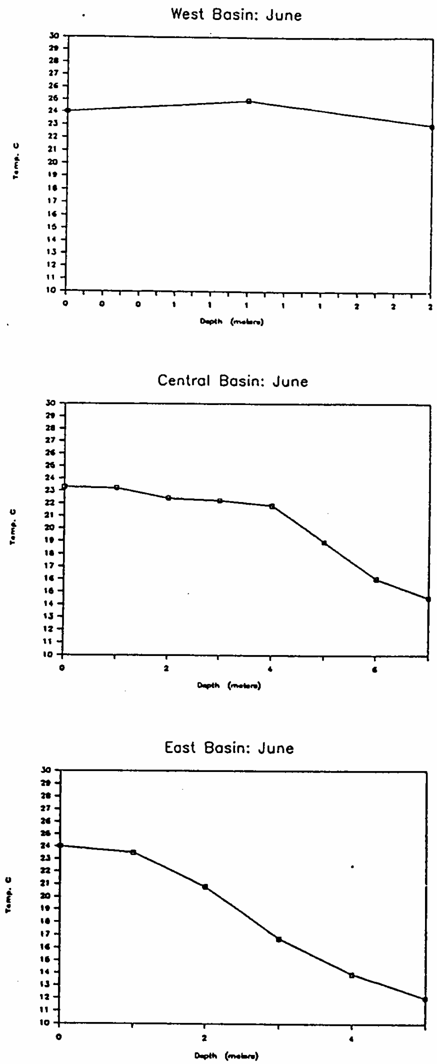


Figure 5. Water Column Temperature Profiles for the Three Basins of Koontz Lake during June 1988.

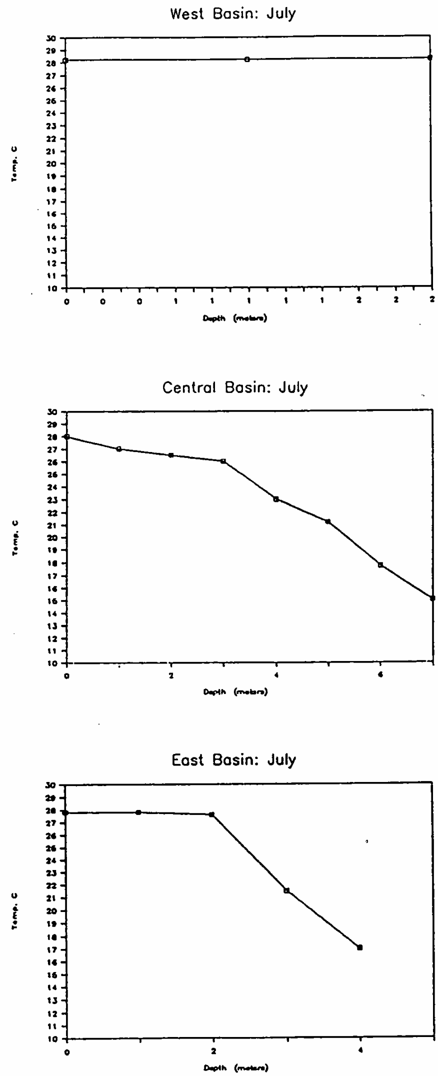


Figure 6. Water Column Temperature Profiles for the Three Basins of Koontz Lake during July 1988

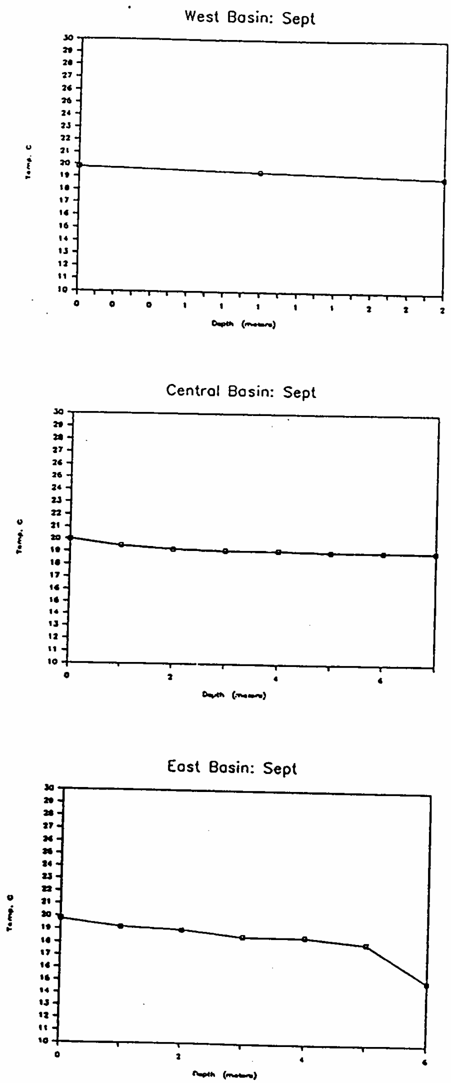


Figure 7. Water Column Temperature Profiles for the Three Basins of Koontz Lake During September 1988

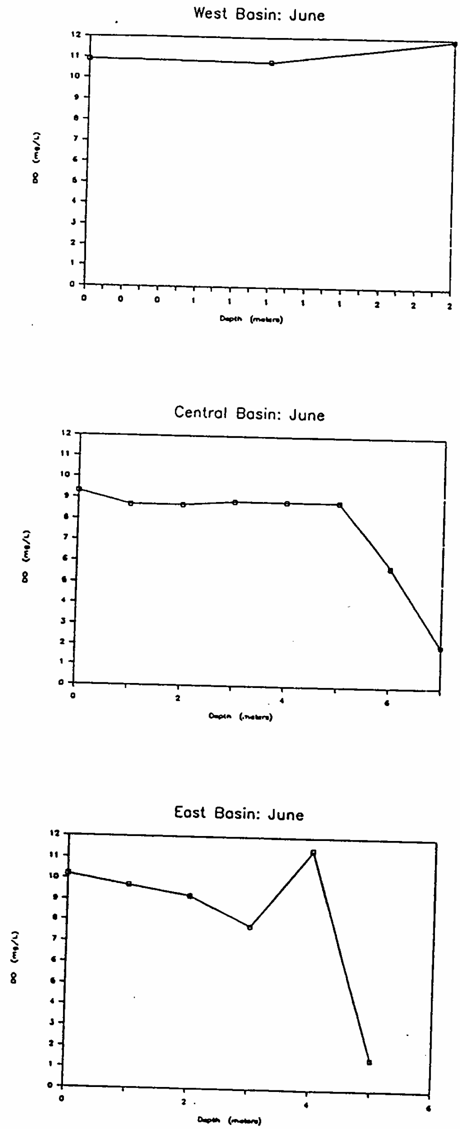


Figure 8. Dissolved Oxygen Profiles for the Three Basins of Koontz Lake during June 1988

in the stratified period of summer, these basins were displaying symptoms of severe eutrophication. The increased oxygen zone at the bottom of the epilimnion of the east basin is attributed to a dense layer of algae. By contrast, the unstratified west basin was uniformly well oxygenated throughout the water column.

Water column deoxygenation of both the east and central basins was even more pronounced during July (Figure 9). Not only had the oxygen of the hypolimnion been seriously depleted, but the portion of the water column affected was greater reflecting the reduction of the depth of the well mixed zone (epilimnion). Again, the west basin was oxygenated throughout its water column reflecting its lack of thermal stratification.

The effect of stratification on water column oxygen concentrations is clearly demonstrated by the September oxygen profiles (Figure 10). Stratification had broken down by September, and oxygen could thus be replenished to the depths of both the central and west basins. Only the east basin displayed some deoxygenation of the water column, and this was limited to the zone immediately above the sediment surface, a zone of intense microbial activity and decomposition.

When expressed as a mean for the entire water column, the central basin displayed the lowest dissolved oxygen of the three basins during June 1988 (Figure 11). The west basin had the highest value, with the east basin being intermediate. The positioning of the central basin is explainable by its greater depth, while that of the west basin is the result of the lack of pronounced thermal stratification. The central basin continued to have the lowest mean value during July, but the east and west basins switched position. By September, the east basin had replaced the central basin as the lowest mean dissolved oxygen, with the west having the highest value.

It is interesting to note that dissolved oxygen in all three basins was greatest during June and least during July. This is not surprising, as it is expected that oxygen will be progressively depleted during the course of the stratification period in highly productive lakes.

Historically, Koontz Lake has displayed severe deoxygenation of the water column during June between 4.6 and 6.1 meters (15-20 feet) depth (Table 3). Comparable 1988 values for the east and central basins were 4-5 meters and 6-7 meters, respectively. The zone of deoxygenation historically has been expanded in the water column during July with serious oxygen depletion occuring below 1.5-4.6 meters (5-15 feet). The 1988 values for July recorded for the east and central basins were 2-3 meters and 3-4 meters,

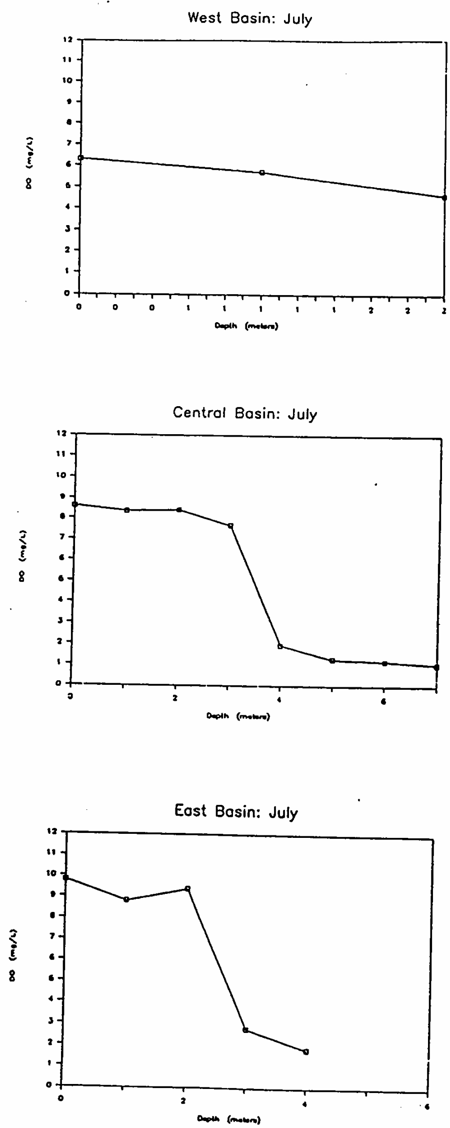
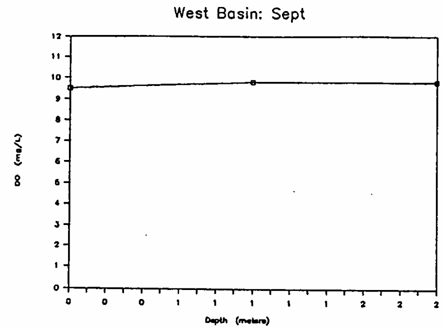
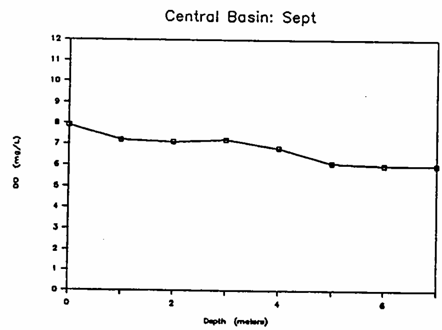


Figure 9. Dissolved Oxygen Profiles for the Three Basins of Koontz Lake during July 1988





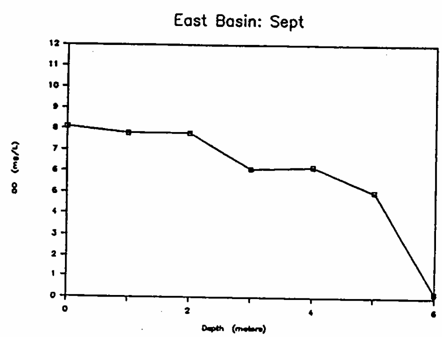


Figure 10. Dissolved Oxygen Profiles for the Three Basins of Koontz Lake during September 1988

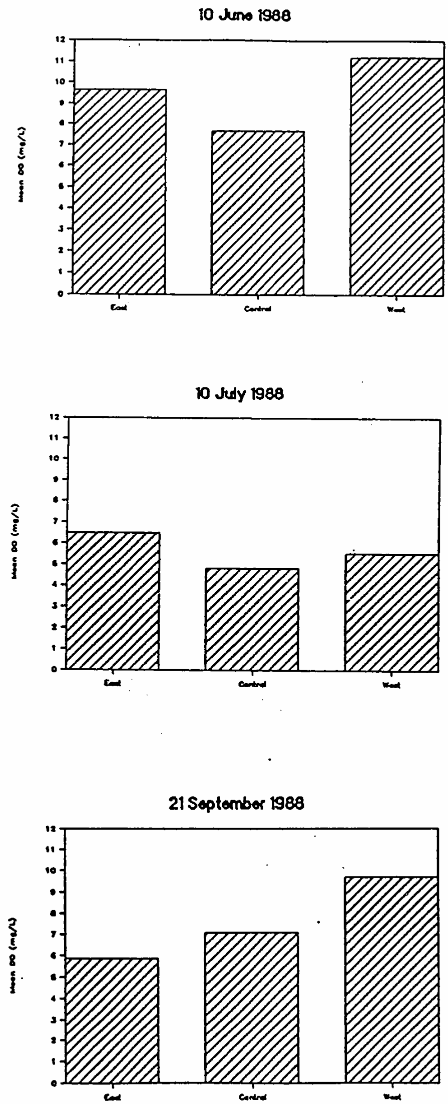


Figure 11. Mean Oxygen Values for the Water Columns of the Three Basins of Koontz Lake during the 1988 Survey

respectively. Thus, it appears that while serious midsummer oxygen depletion is to be expected in Koontz Lake, the severity of this condition has changed little since at least 1965.

Secchi Disc Transparency. As stated earlier in this report, the depth that a secchi disc can no longer be seen in a water column is indicative of the amount of algae suspended in the water column to block light transmission. Thus, the shallower the secchi depth during midsummer, the more productive (eutrophic) a lake is presumed to be. The secchi depth of the central basin was over twice as great as that of the other two basins during June 1988 (Figure 12). The clarity of all three basins was greater during June than later in summer. Although the central basin was still the clearest during July, interbasin differences were greatly diminished. By September, the clarity of the central basin had so decreased that the east basin surpassed it as the clearest basin.

Overall, the central basin displayed the greatest reduction of water clarity during the course of summer, while the west basin displayed the least. This is attributed to the fact that the west basin is well mixed all year, thus constantly recycling nutrients from the bottom. The central basin, by contrast is the deepest basin and thus displays the most stable thermal stratification. Secchi disc transparency data suggest that it is also the least productive of the three basins, and it is only during late summer that algal blooms develop that approximate levels demonstrated by the other two basins throughout the summer.

Finally, comparison of 1988 monthly values with historical data for the same period (Table 2) suggests that the overall summertime water clarity of Koontz Lake appears to be 1-2 feet greater in 1988 than recorded for any time since 1965. This is likely a reflection of the fact that aquatic weeds have greatly expanded during the past 23 years, thereby competing with algae for nutrients. The end result of this competition is a reduction of algal biomass that has led to increased water clarity. There are no data to suggest that water quality has improved markedly during the period. Rather, nutrients are being taken up differentially by weeds.

Ammonia. With the exception of the west basin, ammonia values were lower during June than later in the summer (Figure 13). Throughout the survey, the west basin displayed the lowest ammonia values of the three basins. Ammonia increased in all three basins during July with little differrence being seen between the east and central basins. Interbasin differences were the most pronounced during September, when the central basin displayed the maximum ammonia value for the entire 1988 survey. The trend

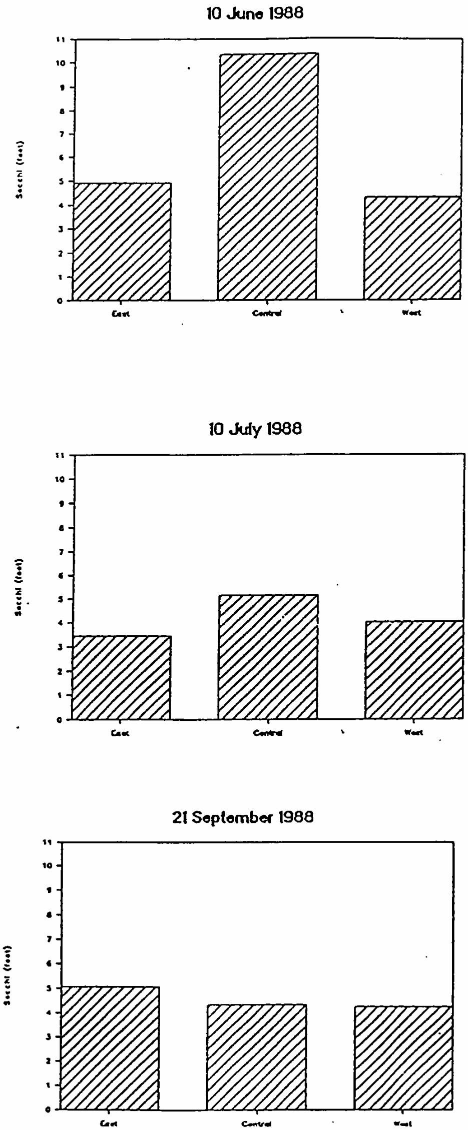


Figure 12. Secchi Depth Transparency for Individual Basins of Koontz Lake during the 1988 Survey

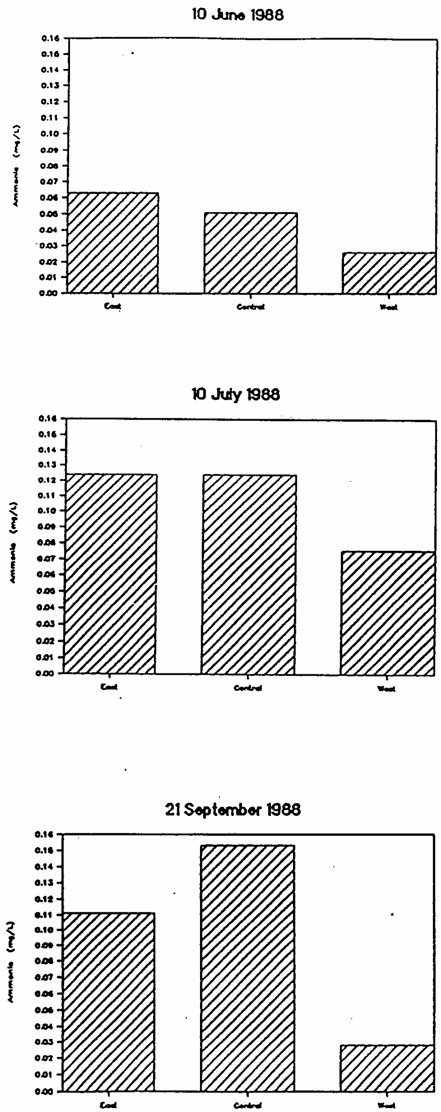


Figure 13. Ammonia Concentrations for Individual Basins of Koontz Lake during the 1988 Survey

displayed for the central basin is consistent with that discussed earlier for secchi transparency and suggests that this basin was displaying progressively more algal productivity as the summer advanced.

Nitrite-Nitrate. With the exception of the west basin, nitrite-nitrate concentrations were greater in June than during the later two sampling periods (Figure 14). The June value for the east basin was the highest concentration of nitrite-nitrate recorded during the 1988 survey. Values for both the east and central basins dropped sharply during July and were only slightly higher than the west basin. Concentrations in the east basin increased slightly during September, while the central basin continued the progressive decline noted throughout the summer. The central basin pattern is consistent with the idea that algal production increased throughout summer in this basin and was the major contributor to the observed decline in secchi transparency.

Kjeldahl Nitrogen. Although interbasin differences were not especially pronounced, the central basin displayed the lowest Kjeldahl nitrogen concentration during June 1988 (Figure 15). Concentrations increased in all basins during July, with the west basin displaying the maximum value of the 1988 survey. All basins declined to minimum survey values during September with little interbasin differences noted.

Total Phosphorus. The west basin displayed slightly higher total phosphorus concentrations than the other two basins during June (Figure 16). Values for all three basins were the lowest of the survey during July with the east basin being two times higher than the other basins. Total phosphorus values increased in all three basins during September, with those of the east and central basins being the maximum recorded during the survey.

The decline noted by all basins during July is not unexpected. Algal and weed production should be maximal during midsummer, thus scavenging phosphorus from the water column for plant growth. In addition, phosphorus in thermally stratified basins (east and central) would be expected to be trapped in the lower portions of the water column as algae sink and decompose. Although unstratified, the west basin has extensive weed growth that appears to have acted effectively at removing phosphorus from the water column. The dramatic increase in phosphorus concentrations in both the east and central basins during September is directly related to the breakdown of thermal stratification and the recycling of phosphorus from the deep anoxic zone throughout the water column. The pulse in the west basin is likely the result of scenescence of the weed community and associated release of phosphorus into the water column.

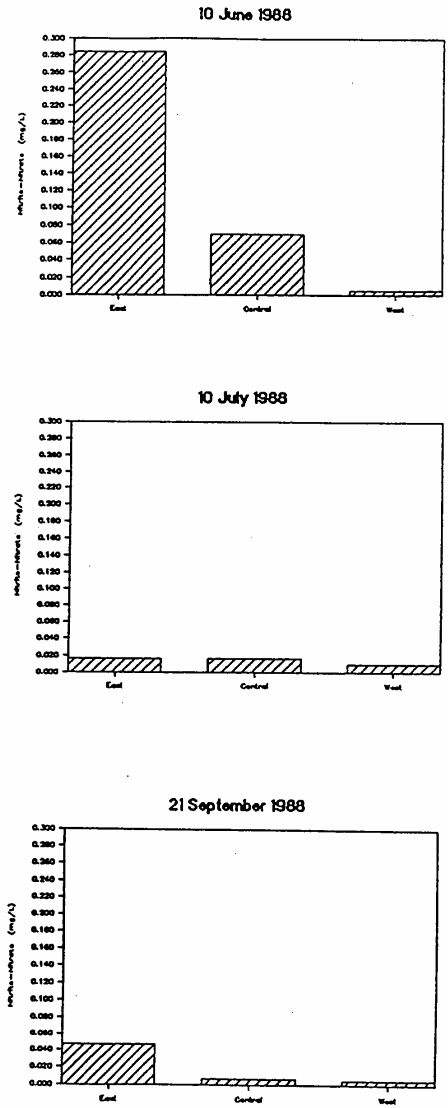


Figure 14. Nitrite-Nitrate Concentrations for Individual Basins of Koontz Lake during the 1988 Survey

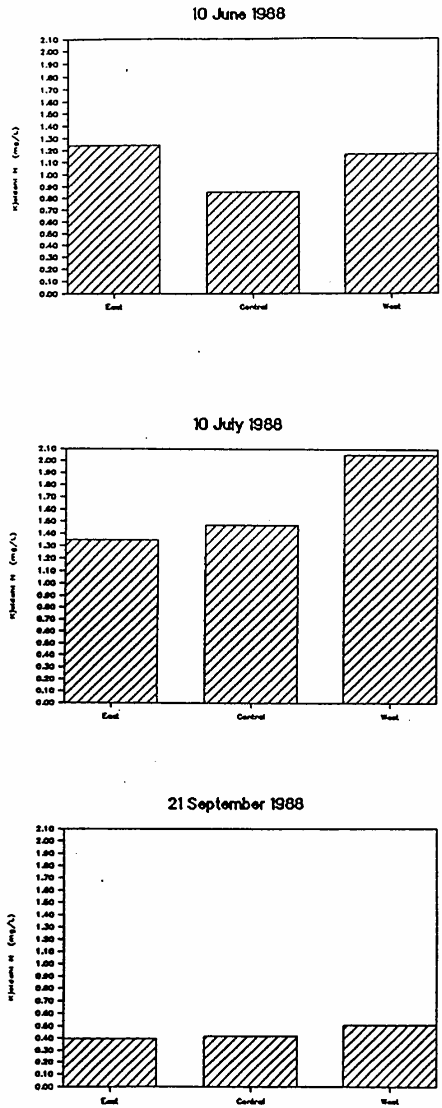


Figure 15. Kjeldahl Nitrogen Concentrations for Individual Basins of Koontz Lake during the 1988 Survey

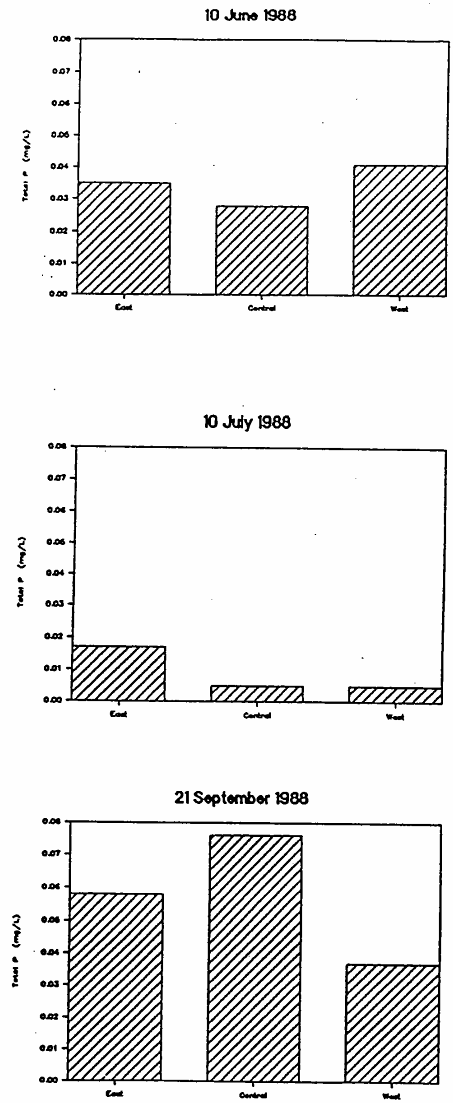


Figure 16. Total Phosphorus Concentrations for Individual Basins of Koontz Lake during the 1988 Survey

Total phosphorus concentrations for 1988 appear to be within the range of summertime values recorded since 1969 (Table 2). It is important to note, however, that water column concentrations of phosphorus are somewhat misleading estimates of trophic state. It is entirely possible that total phosphorus loading to a lake could have increased markedly between years, while water column values decreased. In lakes such as Koontz, which have experienced pronounced increases in weeds, the phosphorus that is entering the system can be effectively trapped by the weed mass and actually decrease in the water column through effective competition with algae for this essential nutrient.

Chlorophyll. Chlorophyll is a good estimator of algal biomass in a lake. Values for June in the east and central basins were the lowest of the survey, and little interbasin differences were noted among the three basins (Figure 17). Concentrations in the east basin reached maximum survey values during July, while those of the west basin were the survey minimum. By September, values in the east and central basins had declined, those of the west basin increased resulting in a reduction in the extent of interbasin differences noted during July. Chlorophyll values from Koontz Lake generally were within the range exhibited by mesotrophic and eutrophic lakes.

ISBH Trophic State Index

Mr Harold BonHomme of the Indiana State Board of Health devised a eutrophication index specific to Indiana lakes based on summertime sampling of 307 lakes in the mid 1970's. Parameters included in the index construction were phosphorus, nitrogen forms, dissolved oxygen, light penetration and transmission, and phytoplankton abundance and group dominance. Ranges for each parameter were assigned eutrophy points, and the final eutrophication index value for a given lake represented the sum of eutrophy points from all parameters combined.

The 1975 eutrophication index for Koontz Lake was calculated by the Indiana State Board of Health as 42, thus assigning the lake to the category of intermediate water quality, class II. In the current survey, we have calculated the eutrophication indices separately for the three basins of Koontz Lake. Means of the three sampling dates were used as parameter estimates for construction of the 1988 indices. As in 1975, the summertime algal flora continued to be dominated by *Aphanizomenon*, *Anacystis* and secondarily by *Fragilaria*.

The 1988 eutrophication indices for the east, central and west basins of Koontz Lake were 41, 32 and 38, respectively. The mean value for Koontz Lake during 1988 was

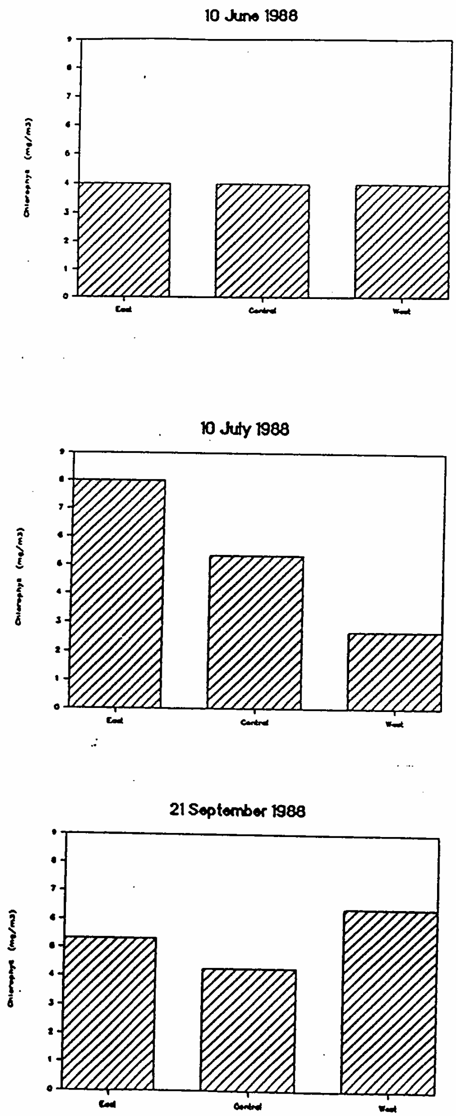


Figure 17. Chlorophyll Concentrations for Individual Basins of Koontz Lake during the 1988 Survey

37 compared to 42 in 1975. The highest trophic state in 1988 was recorded in the east basin, the area of the lake adjacent to the stream that drains the major portion of the watershed. By contrast, the lowest value was recorded in the central basin which is both the largest and the deepest of the three basins of Koontz Lake. This is not unexpected in that the central basin would have a greater assimilation capacity for a given nutrient loading because of its larger volume and deep-water (hypolimnion) nutrient trap, thus minimizing the biological response to a given nutrient concentration.

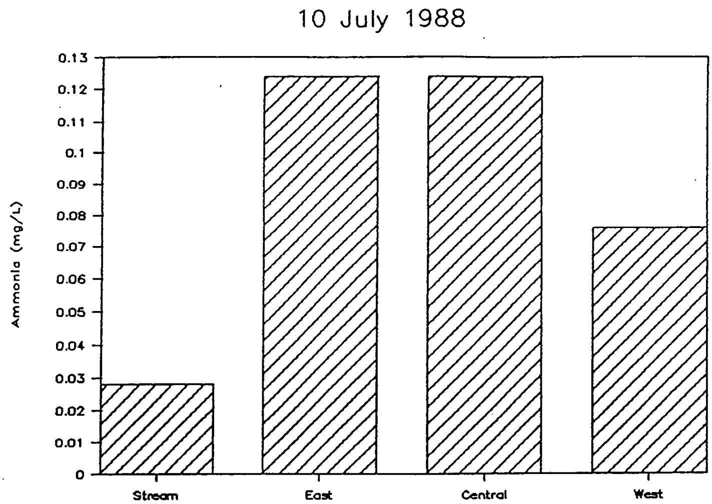
Although it is tempting to suggest that Koontz Lake is displaying better water quality in 1988 than in 1975, such an interpretation must be approached cautiously. It must be kept in mind that the eutrophication index is an estimate of the water column conditions, and like all indices, does not include the extent and productivity of aquatic weeds. Historical evidence suggests that the extent of aquatic weeds in Koontz Lake has been expanding over at least the last decade. Thus, while the overall nutrient loading to the system could have remained constant or even increased, an increasing percentage of this could have been tied up in weeds. Under these conditions, water column conditions would suggest an improvement in overall water quality, while in fact the productivity of the lake had increased, only now being largely in the form of aquatic weeds.

Stream Chemistry

Lawrence Pontius Ditch, the stream draining the majority of the Koontz Lake watershed, was sampled for water chemistry on 10 July 1988. Samples were taken immediately downstream from the last road bridge to cross the ditch before it entered the east basin of Koontz Lake. Extreme drought during the summer of 1988 so reduced flow in the stream as to make sampling for water chemistry at other times unfeasible. Samples for water chemical analyses were treated in the same manner as lake samples described in an earlier section of this report.

The ammonia nitrogen concentrations for both the Pontius Ditch and individual basins of Koontz Lake are presented in Figure 18. The stream value was only approximately 25% that of the east and central basins. By contrast, Kjeldahl nitrogen for the stream was similar to that of the east basin (Figure 18). Values for this nitrogen parameter displayed a progressive increase from the inlet of Pontius Ditch through the three basins of the lake.

The most dramatic difference between the stream and lake stations was seem for nitrite-nitrate nitrogen (Figure 19). The concentration for this nitrogen parameter was



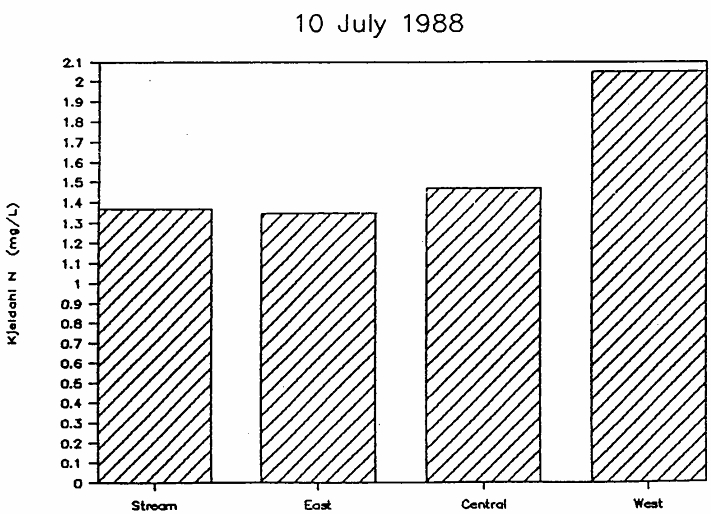


Figure 18. Ammonia and Kjeldahl Nitrogen Concentrations from Pontius Ditch Compared with Koontz Lake Stations for 10 July 1988

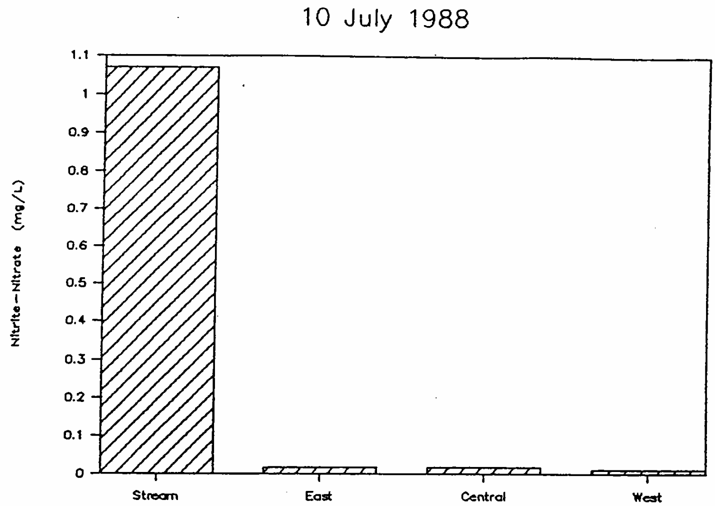
clearly over ten times greater in the stream than at any lake station. Values within the lake displayed little interbasin differences. Of all nitrogen forms, it is readily apparent that Pontius Ditch is the major contributor of nitrite-nitrate nitrogen.

Total phosphorus in Pontius Ditch was only one third that found in the east basin. When compared to the central and west basins, however, the stream and lake values were essentially identical (Figure 19). The enrichment of the east basin for phosphorus relative to the other basins suggests a build up of phosphorus from stream input with delayed flushing of this nutrient to the other two basins of the lake. The extent of urbanization around the east basin is similar to that of the rest of the lake. Thus, it is expected that the input of phosphorus from septic tanks would be similar for a comparable length of shoreline. In addition, the west and east basins are of similar size, but the latter had over three times the phosphorus during July.

It is easy to over interpret chemical data based on a single event sampling. The summer of 1988 was highly unusual and represented one of the worst drought periods in the last one hundred years. Stream flow was minimal throughout our investigation and was considered insufficient to give meaningful chemical data. We do feel, however, that the east basin water chemistry for a given date is an integration of several weeks or months of stream input from Pontius Ditch, and is a much better indicator of the contribution of nutrients from the stream than point samplings of the stream.

Microbiology

Water samples for fecal coliform analysis were collected from each of the three basins of Koontz Lake on 21 September 1988 and were analyzed within eight hours. The analyses followed the state approved membrane filter procedure. Concentrations of fecal coliform bacteria in the east, central, and west basins for this date were 45, <10, and 11 mpn/100 mL of water, respectively. The maximum values were recorded in the east basin, but even these were well within state standards. The 1988 values were lower than recorded previously in 1971 and 1978, which were also within state standards. Based on data collected after 1971 and the current survey, it is felt that there is not a fecal contamination problem in Koontz Lake.



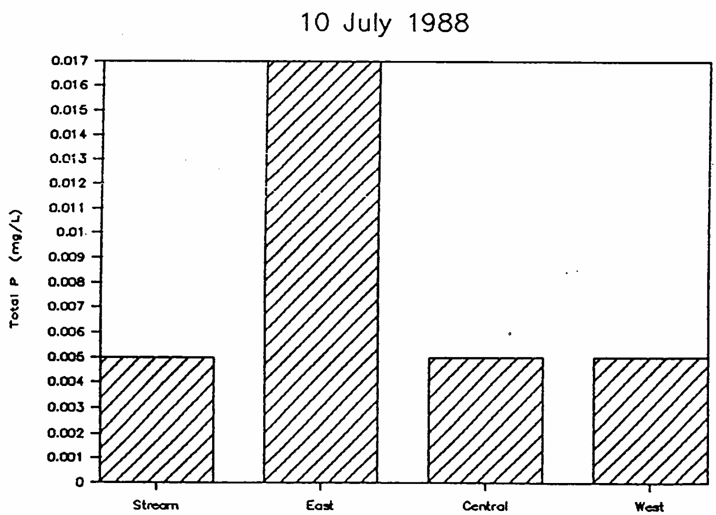


Figure 19. Nitrite-Nitrate and Total Phosphorus Concentrations from Pontius Ditch Compared with Koontz Lake Stations for 10 July 1988

Macrophytes

A raytheon recording fathometer was used to estimate the biovolume of aquatic weeds in the three basins of Koontz Lake. A total of 37 transects spanning the width of the basins were used as the data base. The plant survey was conducted in July 1988 and thus represents midsummer plant extents. Plant biovolume is defined as the percent of the water column at a given location in the lake that is filled with plant biomass. Thus, it is a measure of the extent of weed infestation throughout the lake system.

The distribution of plant biovolume in the entire Koontz Lake system is presented in Figure 20. This figure demonstrates the extremely patchy distribution of plants in the lake. A much more informative way of looking at the data is to plot biovolume in increments of 20% water column infestation (Figure 21). The nearshore areas of all three basins were considered 100% infested with weeds in 1988. This is a refection of the shallow water depth permitting light to reach the bottom and the growth habit of grasses and other emergent weed taxa. Thus, the 100% zone corresponds with the extent of grasses near shore. This zone reached its greatest extent in the center basin. The zone of 80% infestation reached its greatest extent in the east basin. In all basins it was rather narrow in its extent and was restricted to water less than 5 feet in depth.

The 60% infestation zone was restricted to water slightly deeper than the 80% zone and reached its greatest extent in the center and east basins. Progressively deeper water was indicated by the 40% and 20% zones with the former displaying greater aerial extent. Finally, areas deeper than 15 feet in the east and center basins had <20% water column infestation with aquatic weeds. The depth limitation of this zone in the west basin was much shallower than observed in the other two basins, and began in water 5-10 feet deep.

Figure 22 summarizes the distribution of plant biovolume in all three basins of Koontz Lake. Approximately 48% of the west basin displayed water column plant infestation <40%, while over 42% of the area of the center basin had <20% infestation. The other end of the spectrum is provided by the east basin, where over 54% of the lake area had water column infestation exceeding 80%. Over half of this estimate was considered 100% infested. The east basin clearly has the most serious weed problem followed by the west and center basins, respectively. The latter basin is considered to have a balanced weed community that does not pose any serious large-scale management problems.

We also determined the height of plants throughout the Koontz Lake system (Figure 23). A clear picture of plant

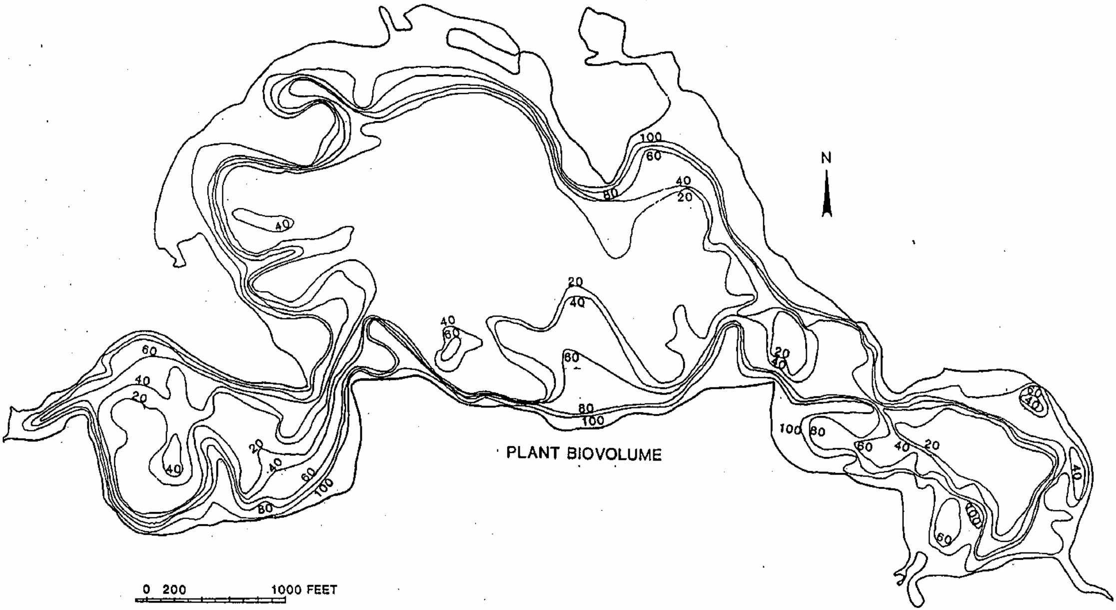


Figure 20. Distribution of Aquatic Weed Biovolume in the Koontz Lake System for 1988

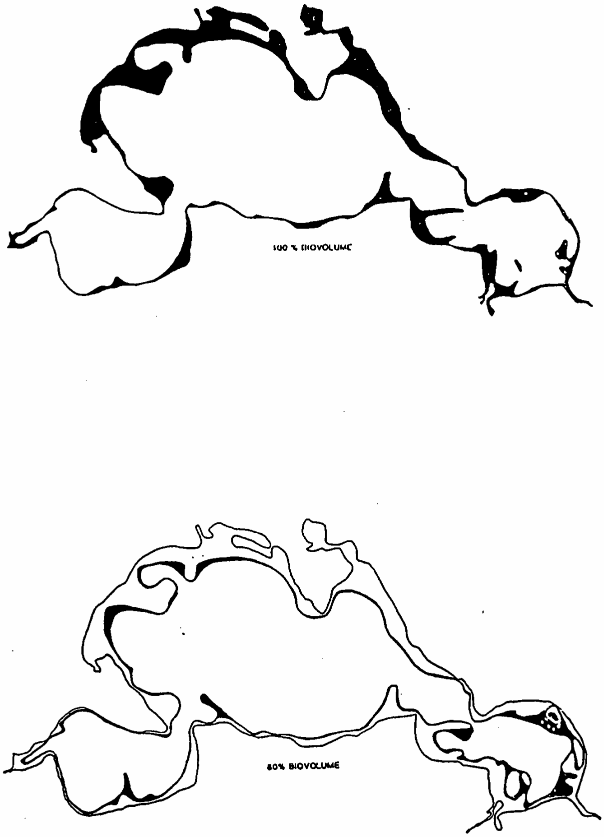
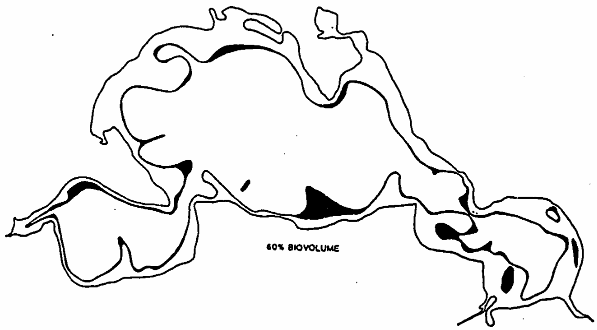
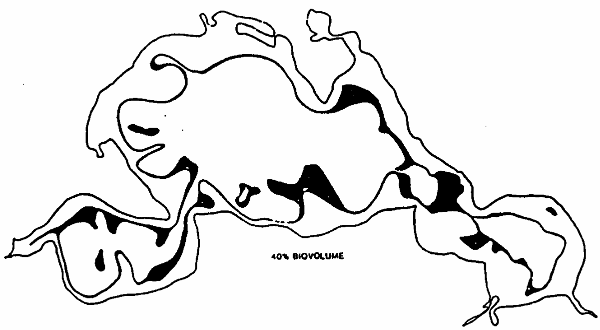


Figure 21. Plant Biovolume in Increments of 20% Water Column Infestation at Koontz Lake in 1988





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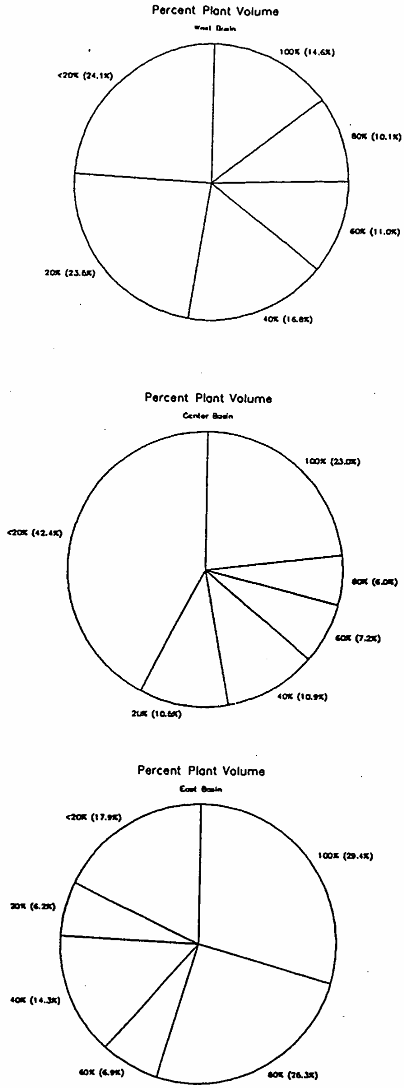


Figure 22. The Distribution of Plant Biovolume in the Three Basins Expressed as a Percent of Water Column Infestation

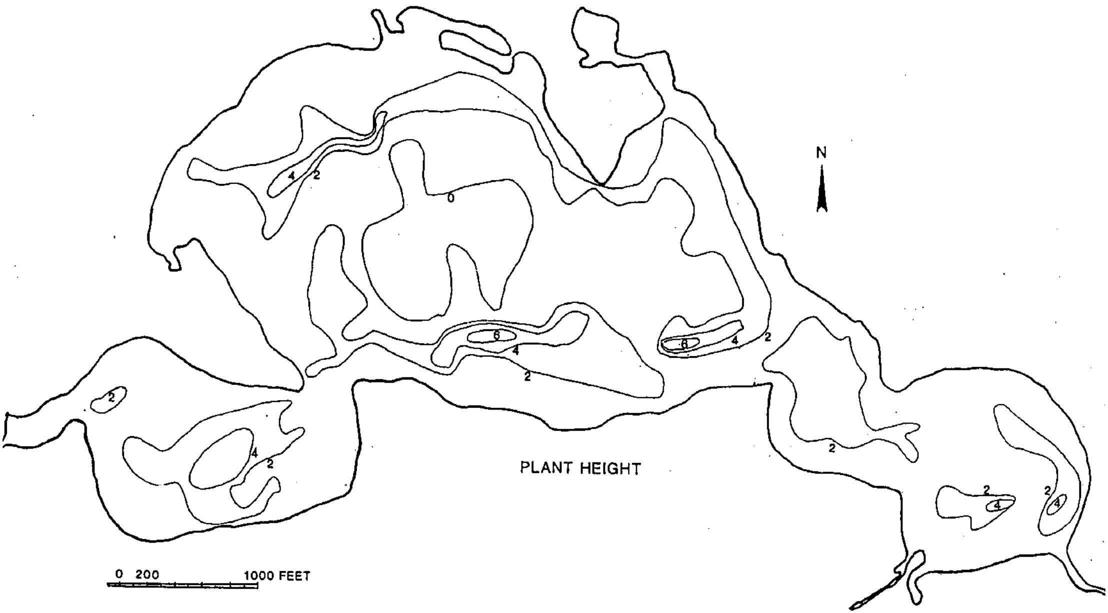


Figure 23. The Height of Aquatic Weeds Throughout the Koontz Lake System

distribution is seen when zones of plant height are defined at 2 foot height intervals (Figure 24). Only two tiny areas of the center basin had weed growth that exceeded 6 feet. The deeper section of the west basin displayed plant growth that often ranged 4-6 feet, while little excessively tall plant growth was seen in the east basin. A majority of the plant standing stock in the entire Koontz Lake system was < 2 feet tall. In the nearshore areas this reflects the extremely shallow water and the fact that the total water column in such areas is likely infested with weeds. In deeper areas of all basins, plant growth is limited by light, where little excessive growth can be expected much below the Secchi disc depth. The only area of the Koontz Lake system devoid of plant growth was the deepest section of the center basin where water depths exceeded 25 feet. This area was totally devoid of light.

In addition to looking at the distribution of plant biomass in Koontz Lake, a qualitative survey was made to determine the distribution of the major plant species in the system. Drawings of the major plant taxa encountered in Koontz Lake are given in Figure 25, and the distribution of these in all three basins is presented in Figure 26. Large sections of the west basin were dominated by an algal mat that blanketed the bottom. Although covering large areas, this mat never exceeded 2 feet in height. Only the west basin displayed any extensive coverage by the macroalga Chara. This plant precipitates calcium carbonate on its surface giving a sand paper feel. Chara rarely causes plant management problems in lakes. It reached its greatest extent along the northern shore of the west basin. Various taxa of pondweed (Potomogeton) were scattered throughout the west basin. This plant often produces tall stems that nearly reach the water surface and is an important food for water fowl. It is not considered a problem in the west basin. Finally, some yellow water lilies (Nuphar) were found at the entrance to the center basin. These are rarely considered problems and are important nesting areas for sunfish species.

The flora of the center basin was dominated by several species of pondweeds and coontail (Ceratophyllum). While mixed in with pondweeds near shore, the latter developed nearly pure stands in water 5-10 feet deep. Yellow water lilies were most common along the west shore near the entrance to the west basin and along the entire eastern shore. One taxon not identified in previous surveys by the Indiana DNR was eelgrass or tapegrass (Vallisneria). This plant was in often dense patches along the northern shore of the basin. It is considered a beneficial species and should be left alone. As mentioned previously, the plant community of the center basin is considered well balanced and should not be disturbed as part of a weed control program.

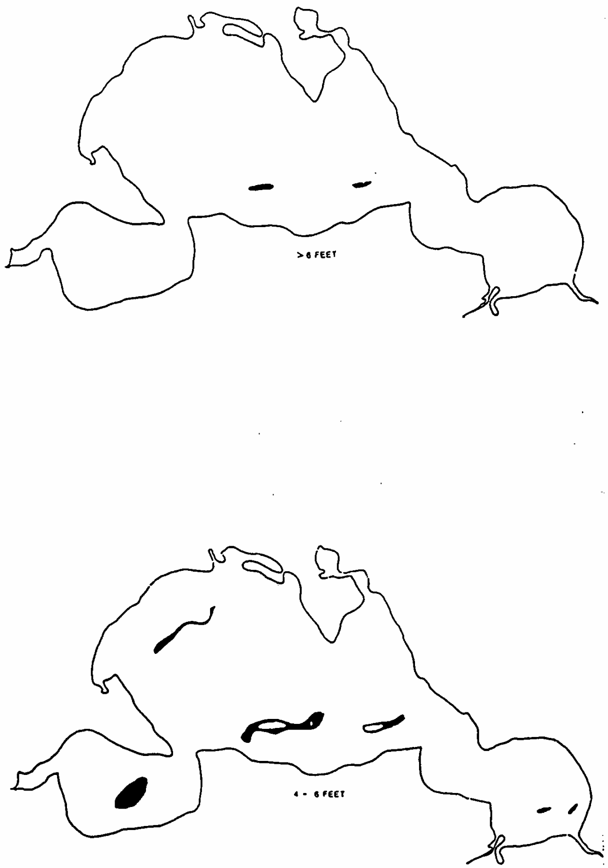


Figure 24. The Distribution of Aquatic Plant Height in the Koontz Lake System by 2 Foot Height Increments

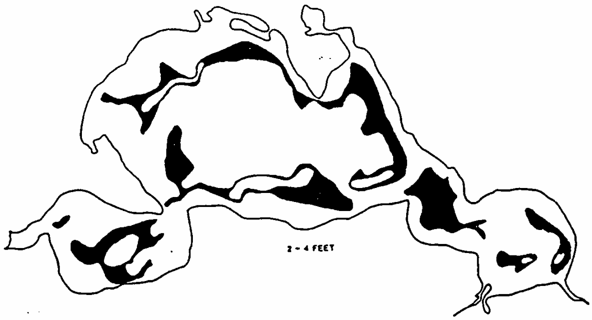
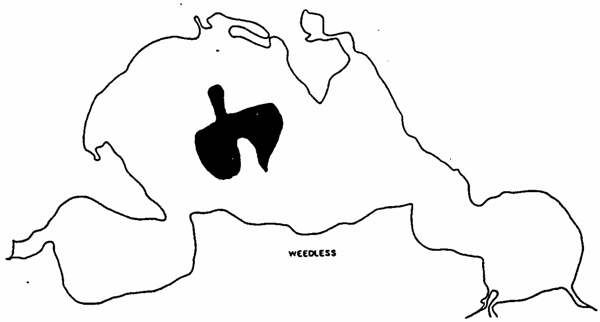


Figure 24. (cont'd)



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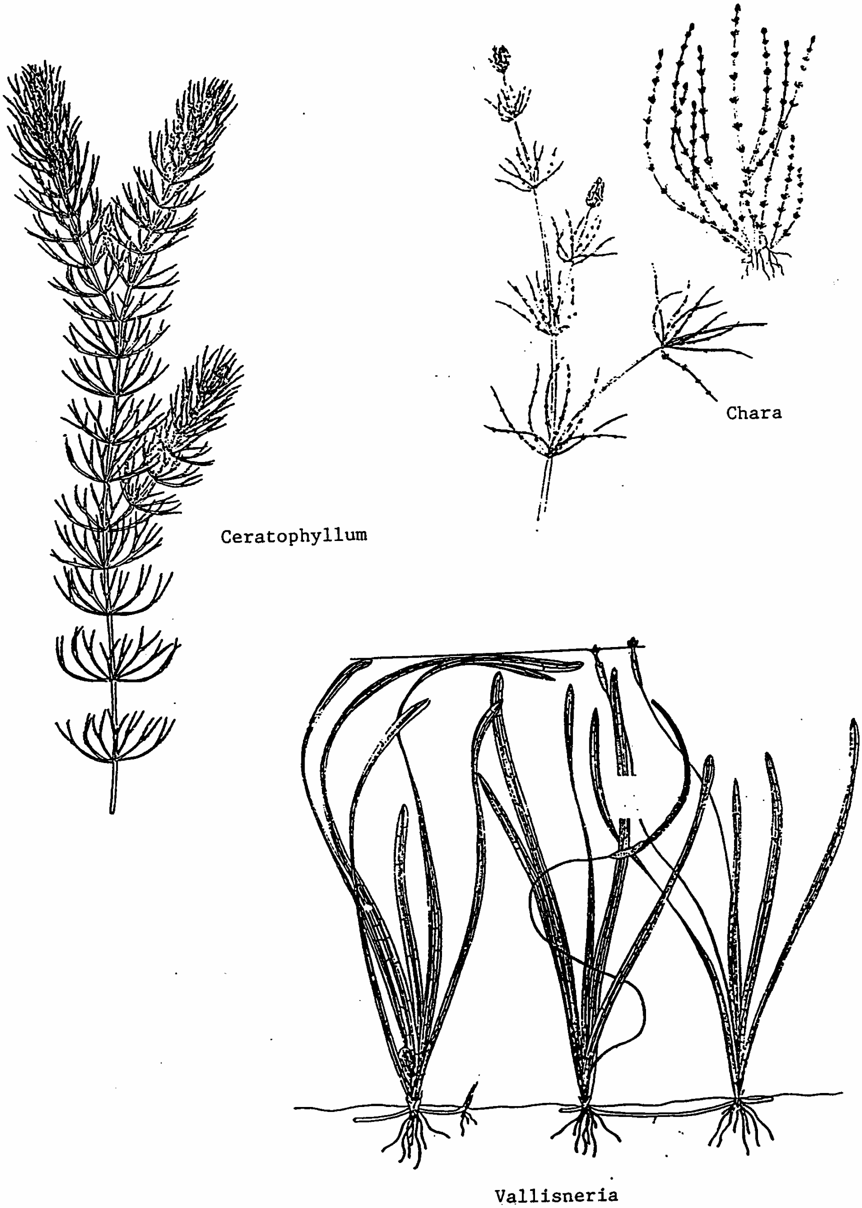
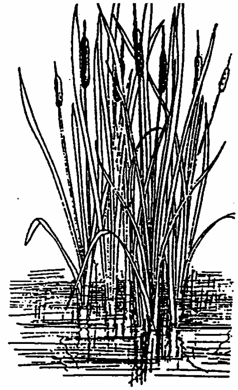
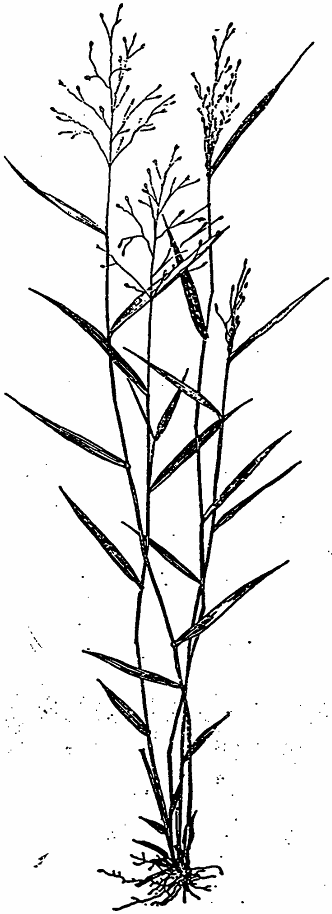


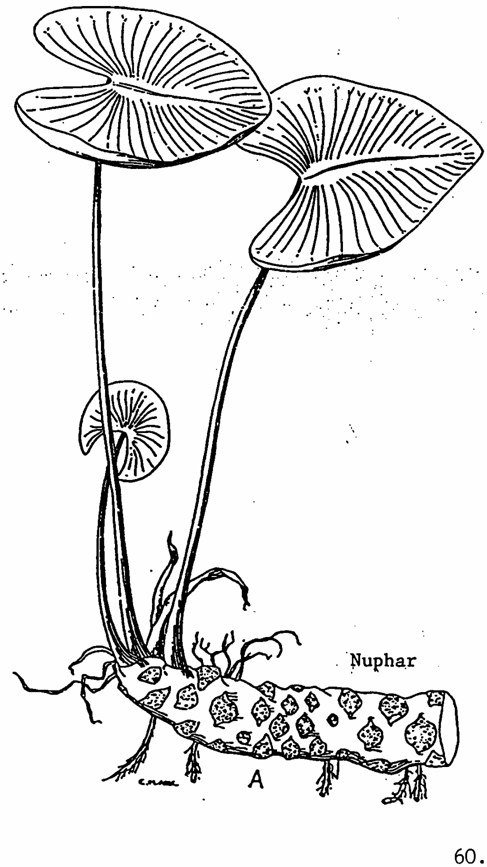
Figure 25. Common Plant Taxa Found in Koontz Lake during 1988



Typha



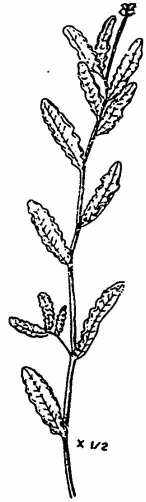
Grass



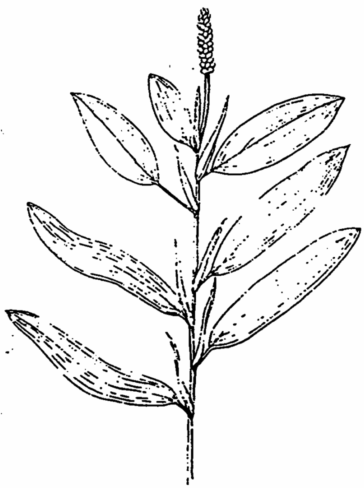
Nuphar

Figure 25 (cont'd)

Potamogeton

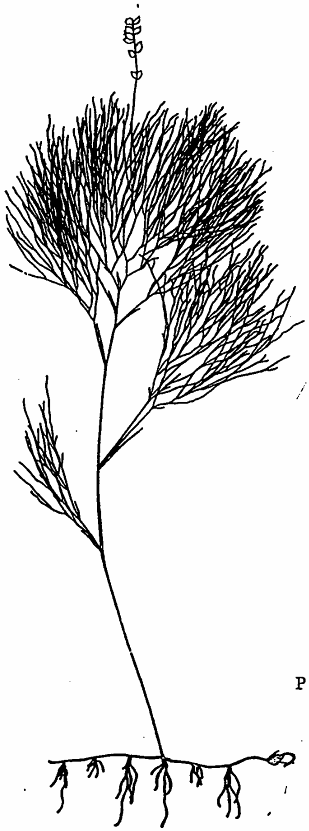


P. Crispus



P. Illinoensis

Figure 25. (cont'd)



Potamogeton

P. Pectinatus

Figure 25. (cont'd)

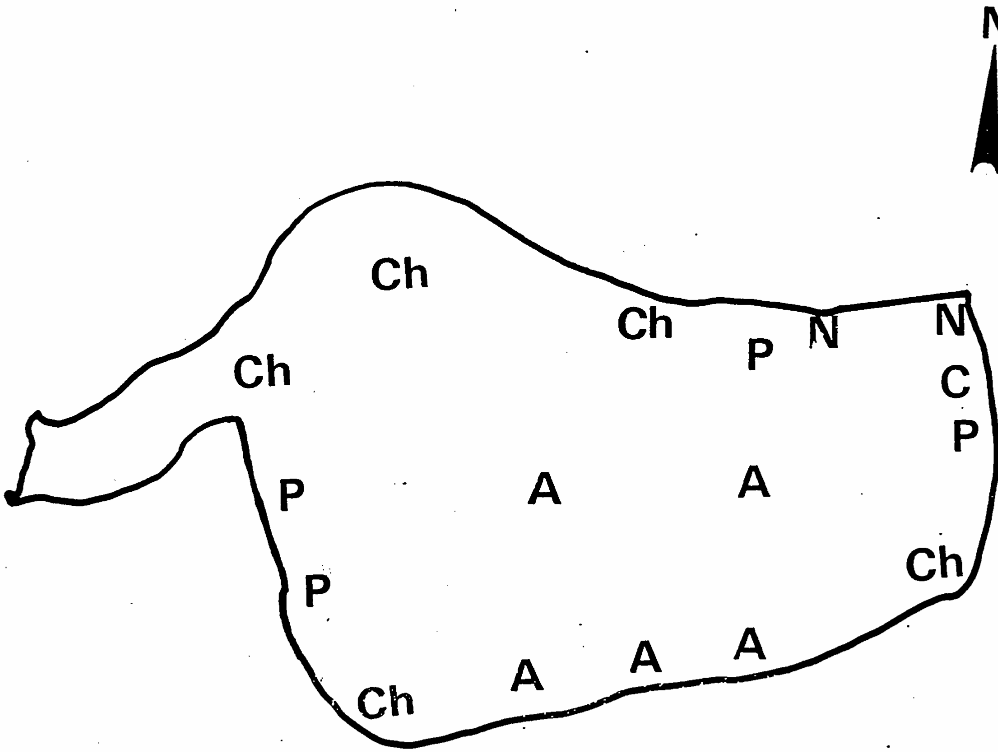
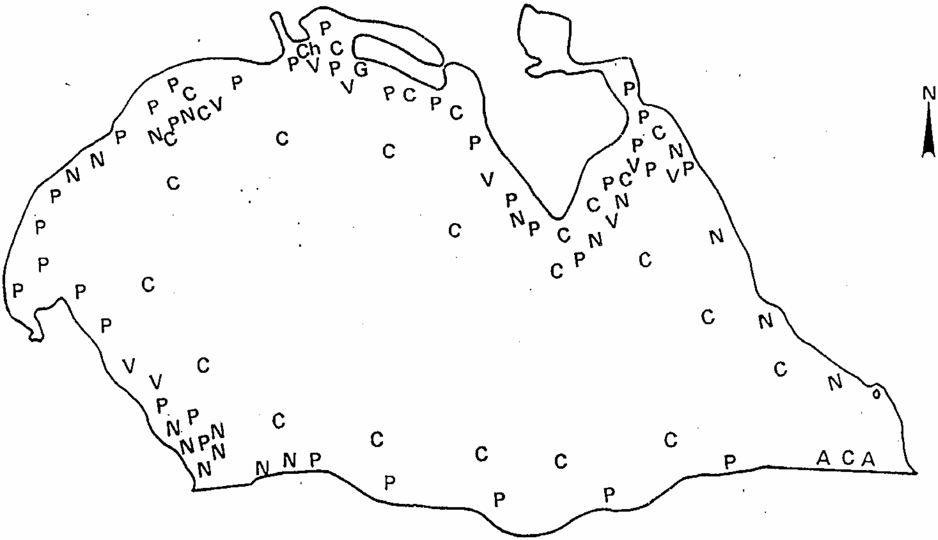


Figure 26. Distribution of Major Plant Taxa in the Three Basins of Koontz Lake in 1988. Plants were: Algae (A), Ceratophyllum (C), Chara (Ch), Potomogeton (P), Nuphar (N), and Vallisneria (V)



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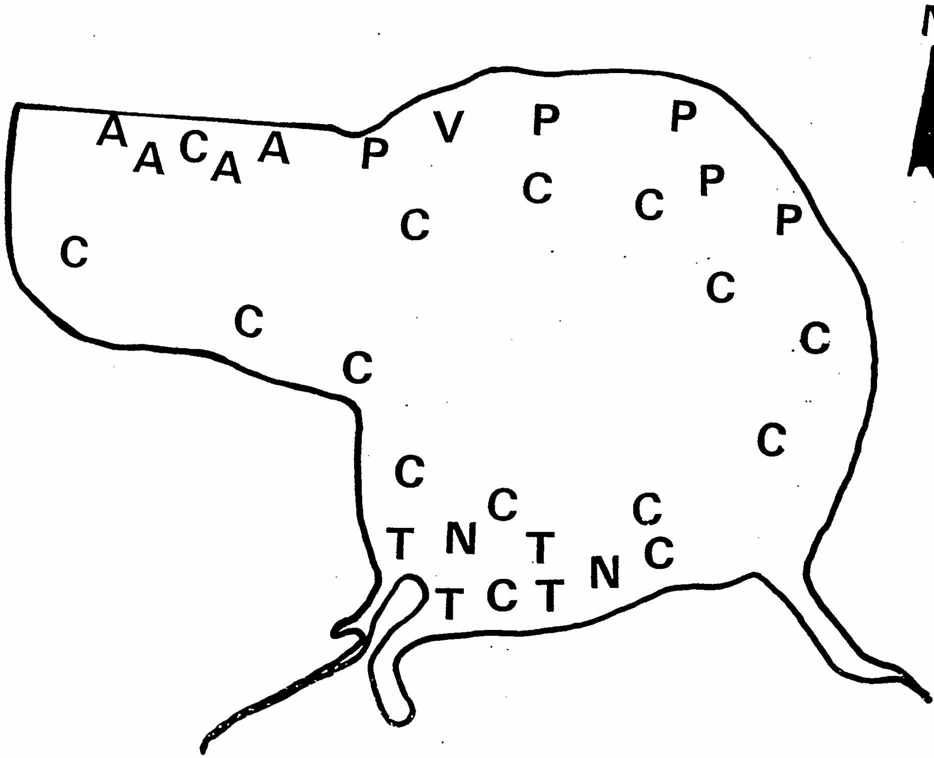


Figure 26. (cont'd)

The east basin at the inlet of Pontius Ditch is characterized by an emergent plant community dominated by cattails and yellow pond lilies. As will be clearly demonstrated later in this report, this community has developed on the sediment delta formed from sediment carried by Pontius Ditch and deposited in the east basin. Comparison with earlier accounts clearly demonstrates that this community is ever expanding as the sediment delta builds out into the basin. Coontail is clearly the dominant plant of the east basin with pondweeds as the secondary dominant. All areas of the east basin displaying plant growth 2-4 feet tall are dominated by coontail. General observation was that the richness of the coontail stand generally increased the closer one got to the inlet of the Pontius Ditch. It is clear that coontail is helping to trap nutrients delivered by the ditch, thus competing with algae in the water column. The result is clearer water in the east basin than would be expected if the plants were radically removed and algae began to proliferate. Further, coontail acts to trap the nutrients in the east basin, thus diminishing the nutrient loading to the other two basins. Future plant management must be approached cautiously so as not to short circuit this kidney effect.

It appears that those near shore areas treated with chemicals for weed control during late spring 1988 display both a lower plant biomass and a different plant composition than comparable untreated areas within the basin. Pondweeds have become the dominants in those areas treated with chemical, while coontail continues to dominate in the untreated areas. This appears to be a marked improvement to favor plant species conducive to fish and water fowl.

Fish

The Raytheon fathometer data recorded from the 37 cross lake transects were also used to provide a qualitative assessment of the fish community of Koontz Lake. Echos of fish in the water column appear on all fathometer recordings, and these were used to assess total fish abundance and the depth distribution of the population for each basin.

For interbasin comparison, fish data were presented on the basis of number individuals per 1000 feet of fathometer transect (Figure 27). The largest fish population was found in the east basin followed by the central and west basins, respectively. The estimate for the east basin was almost double that of the west basin. The larger fish population in the east basin is attributed to the fact that this basin also displayed the greatest biovolume development of aquatic weeds. Such proliferation of weeds has provided breeding

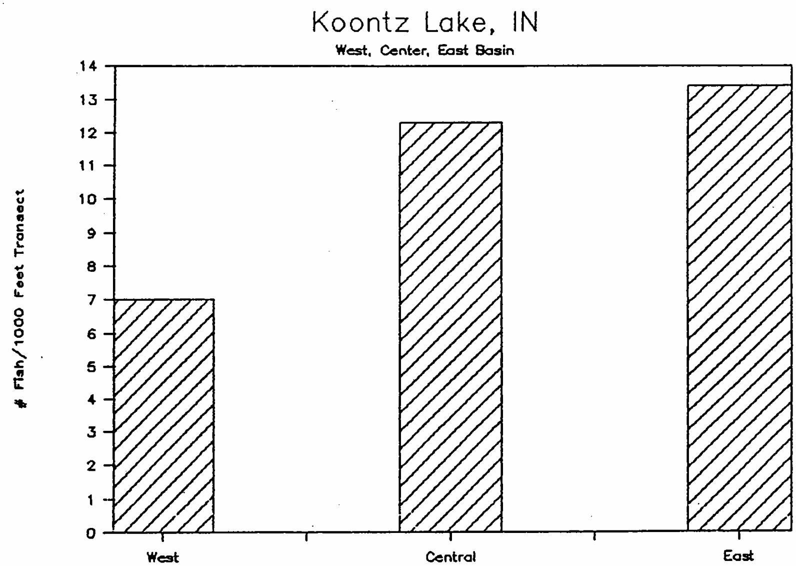


Figure 27. Semi-Quantitative Estimate of Fish in Koontz Lake Expressed as Number Individuals Per 1000 Feet of Fathometer Transect

habitat, protection of young from fish predators, and likely an expanded food base for many of the sunfish taxa that feed on the benthic invertebrates using the weeds as a substrate. These data indicate only that fish are abundant in this basin, but suggest nothing about the overall fitness of the population. Experience elsewhere has suggested that excessive weeds may lead to a reduced quality of the fish population while promoting increased fish abundance. The former is of supreme importance to the average fisherman.

The high fish population in the center basin is not surprising given that this basin displays the greatest habitat diversity as witnessed by its greater depth and species rich weed assemblage. Although the west basin displayed the second highest trophic state index of the three basins for 1988, it had the lowest fish population. This basin is the shallowest basin and thus it is likely that the fish were moving to the deeper central basin to avoid the excessive temperatures experienced during the summer of 1988. It is expected that fish populations should be higher in this basin during a normal summer.

The depth distribution of the fish populations of each basin of Koontz Lake for July 1988 are given in Figure 28. A similar pattern is displayed by the east and central basins whereby nearly 20% of the fish population was concentrated at a depth of 8 feet. Fish appeared to be avoiding the high temperature shallow depth as well as the oxygen depleted lower portions of the water column. The eight-foot depth corresponds to the bottom of the well oxygenated upper portion of the water column (epilimnion). It is suggested that the fish are seeking the coolest water possible that still has sufficient oxygen to keep them from being stressed.

The pattern of the west basin is different in that the maximum concentration of fish occurred at a depth of 4 feet. Most of the basin is < 5 feet, thus fish stay as deep as possible to avoid heat stress. This basin is well mixed throughout, and therefore is well oxygenated to the bottom. From a comparison with patterns from the other two basins, it is apparent that the lower overall fish abundance in the west basin is the direct result of the fact that the shallow depth of this basin does not provide sufficient temperature protection, and the fish have migrated to the deeper portions of the other two basins as a cool water refuge.

The overall mean depth distribution for the Koontz Lake system is given in Figure 29. The system pattern approaches a normal distribution whereby fish are clustered at the bottom of the well mixed upper portion of the water column (epilimnion) and avoid the oxygen stress of deep water and the high temperatures of the surface waters. Such a distribution is to be expected during midsummer in

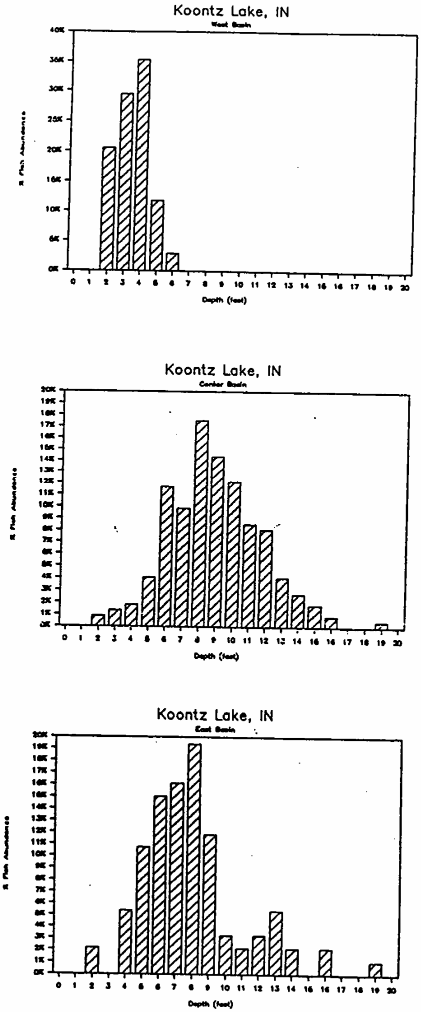


Figure 28. Depth Distribution of the Fish Community in Individual Basins of Koontz Lake during July 1988

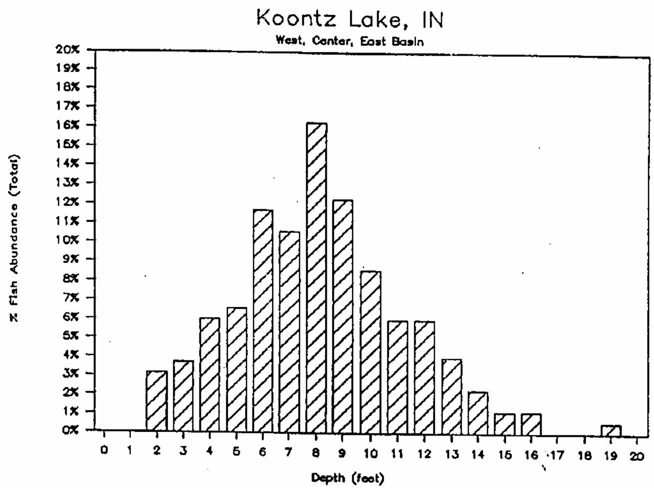


Figure 29. Depth Distribution of the Fish Community for July 1988 Expressed as a Mean for the Koontz Lake System

moderately eutrophic lakes of Indiana. If trophic state can be reduced, the fish abundance in the lake will likely expand as more of deeper the water column becomes available for fish use associated with higher oxygen values.

Bathymetric Map and Lake Infilling

The Indiana DNR in association with the United States Geological Survey published a bathymetric map of Koontz Lake based on a survey of 1955 (Figure 30). Depth contours were constructed at five foot intervals for all three basins of the system. The current study constructed an updated bathymetric map for 1988 based on fathometer recordings obtained from 37 lake transects (Figure 31). Following convention established by the 1955 map, five foot contours were constructed for the 1988 map.

It is obvious that the depth configuration has changed markedly in the past 33 years. A comparison of the depth distribution for the three basins of Koontz Lake in 1955 and 1988 is graphically displayed in Figure 32. The center basin was clearly the deepest of the three in 1955 with a maximum depth of 31 feet. The maximum depths of the east and west basins did not exceed 25 and 15 feet, respectively. The contour interval covering the greatest aerial extent in 1955 was 5-10 feet, with the second greatest extent being the 0-5 foot contour.

By 1988 the picture had completely changed (Figure 32). The maximum depth recorded in the central basin did not exceed 30 feet, while that of the east and west basins had been reduced to 20 and 10 feet, respectively. In addition, the contour interval in the Koontz Lake system displaying the greatest area changed from 5-10 feet in 1955 to 0-5 feet in 1988.

A comparison of interyear differences in the extent of each depth contour has been constructed for each of the three basins of Koontz Lake (Figure 33). Between 1955 and 1988, the west basin lost all areas greater than 10 feet, and the extent of 5-10 foot deep areas was reduced by over 60%. A reverse trend was noted for the 0-5 foot interval, which actually doubled its extent in the 33 year period.

The central basin appears to have lost all areas deeper than 30 feet. Given the small areal extent of this zone even in 1955, one possibility is that the transects constructed during 1988 may have missed this small zone. A second more plausible interpretation is that because the next shallower contour (25-30 feet) was reduced in extent by approximately 20% since 1955, it is possible that the apparent total loss of areas deeper than 30 feet is real.

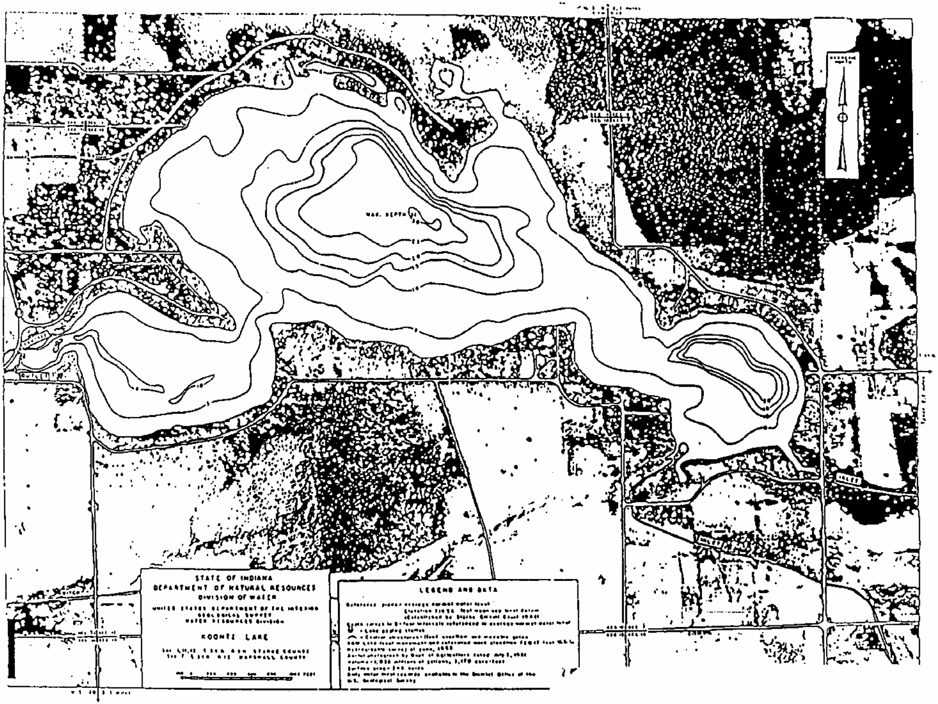


Figure 30. Bathymetric Map of Koontz Lake from 1955

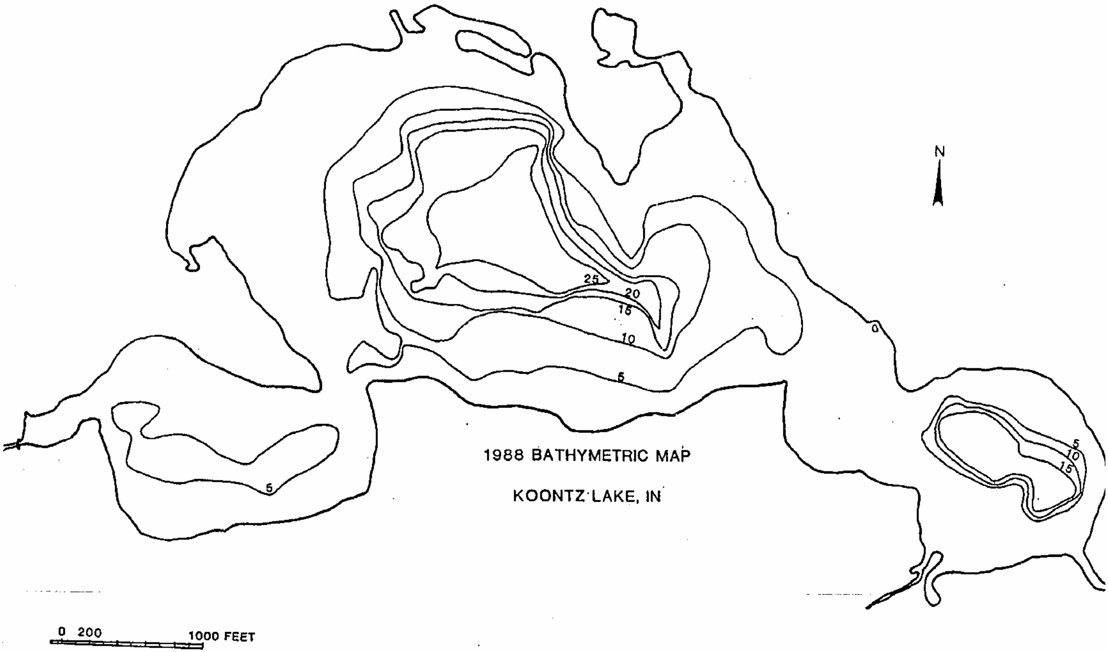
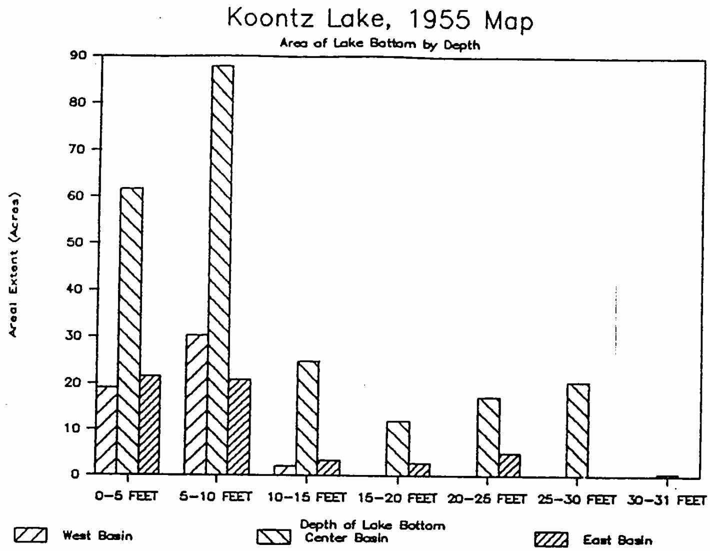


Figure 31. 1988 Bathymetric Map of Koontz Lake



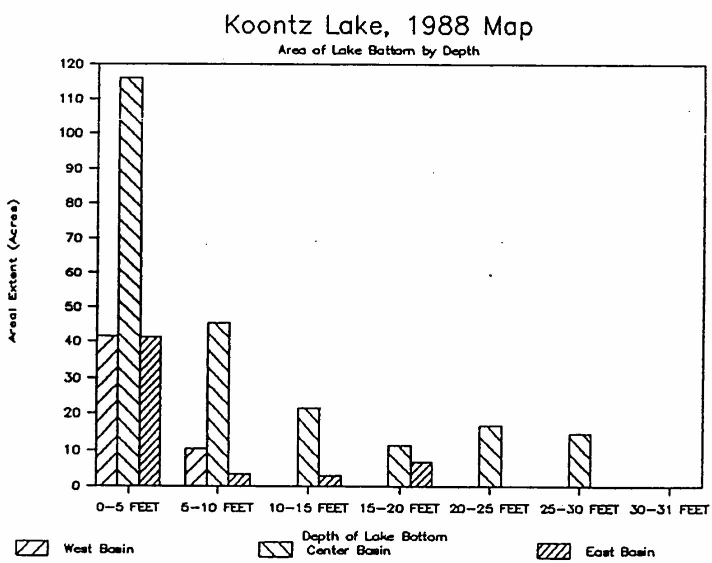


Figure 32. Comparison of Depth Distribution for the Three Basins of Koontz Lake for 1955 and 1988

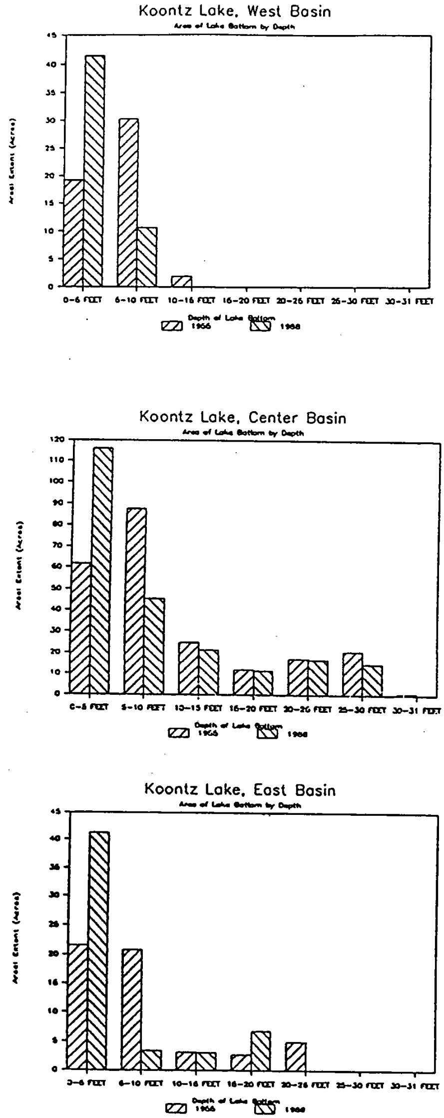


Figure 33. Comparison of the Areal Extent of Depth Contours for 1955 versus 1988 for each Basin of Koontz Lake

Depth intervals between 10 and 25 feet for the central basin displayed little change in areal extent since 1955 suggesting that deposition of sediment was minimal in this section of the basin. As in the west basin, however, the 5-10 foot contour was reduced as the 0-5 foot interval doubled its areal extent.

Finally, the east basin mirrors the trend established by the west and central basins. It is quite clear that all areas of this basin >20 feet were filled in by 1988. The expansion of areas 20-25 feet deep between 1955 and 1988 is further evidence that formerly deeper areas are up to 5 feet shallower. As in the previous two basins, the east basin has experienced a doubling of the 0-5 foot interval. Unlike the west and central basins which displayed an approximately 50% reduction in the extent of the 5-10 foot interval in the 33 year period, however, the reduction in the 5-10 foot interval in the east basin is much more pronounced, being only 14% of its 1955 extent.

Changes in bathymetric maps between 1955 and 1988 were used to calculate annual sedimentation rates in each basin for the last 33 years. For calculation purposes, we have assumed that sediment is spread evenly over all bottom areas of a given basin. We know that sediment collects differentially in basins depending on the source of the sediment, thus, our estimates are considered extremely conservative as basin wide estimates. The calculated mean sedimentation rate for the past 33 years was greatest for the east basin (.84 inches/year) followed by the west (.82) and center (.68) basins, respectively. Total lake wide mean sedimentation rate was .73 inches/year. Please note that such sedimentation rates include both the contribution of inorganic sediment and organic sediments derived from dead algae and macrophytes produced within the lake. We feel that organic matter produced within the basin is the prime contributor to the central basin. The higher sedimentation in the west basin is attributed to the small size of the basin coupled with large production of aquatic weeds. While undecomposed weed material contributes somewhat to the east basin sedimentation rate, we feel that the evidence is abundantly clear that the prime contributing factor is inorganic sediment brought into the basin from Pontius Ditch.

From examination of aerial photos and maps, it is readily apparent that a major sediment delta has formed in the east basin at the mouth of the Pontius Ditch. Our 1988 survey clearly indicates that this stream borne sediment has been largely responsible for the dramatic basin infilling seen in the east basin between 1955 and 1988. It is also likely that some of the shoaling of deeper sections of the center and west basins can also be attributed to transport of sediment from Pontius Ditch throughout the lake system. This is expected given that Pontius Ditch is the principal point source for water coming into Koontz Lake and water flow is generally directed from the east basin, through the center and west basins with system discharge at the water control structure located at the west end of the west basin.

It is equally apparent that sediment input from Pontius Ditch can not fully explain the pronounced shoaling seen in 5-10 foot deep areas of all three basins since 1955. It is obvious that areas 0-5 feet deep are being eroded, and the sediment is being redeposited in the 5-10 foot contour. For both the west and central basins, the former contour interval has been reduced by approximately 50% in the last 33 years, while the latter contour has increased in aerial extent by approximately the same amount during the same period. Such evidence is more than suggestive that sediment is being displaced in these two basins from nearshore areas to deeper areas. Such a trend does not reflect a change in sediment loading to the shallow areas of these basins, rather a mere displacement within each basin. The situation in the east basin is different in that while the 0-5 foot area has doubled as in the other basins, the 5-10 foot interval is now only 14% of the 1955 value. The pronounced change in the 5-10 foot interval can not be explained by redeposition from the 0-5 foot interval alone. It is clear that this basin has experienced a major input of sediment from the Pontius Ditch during the 33 year period.

Two factors are likely responsible for shallow water sediment erosion and associated redeposition in deeper water. The grasses, cattails and other emergent vegetation growing in nearshore areas act to reduce the erosion action of waves. Our research elsewhere has clearly demonstrated that removal of such vegetation by homeowners wanting easier access to their docks enhances the erosion action by waves and thereby promotes shoaling of offshore areas. The second factor for promoting shallow water erosion is waves generated by speed boats. Our research at Lake Maxinkuckee clearly addressed this point. Waves are normally only produced in lakes during storm events. Intense speed boat activity, such as is common at both Maxinkuckee and Koontz, produces waves that approximate those generated during storms. Such waves increase nearshore erosion, stir nutrients from bottom waters and promote algal growth. We are suggesting that a majority of the serious nearshore erosion at Koontz Lake is the direct result of waves generated from speed boats. We could find no evidence that actual shoreline erosion was contributing significantly to the shoaling of shallow (< 10 feet) areas.

Sediment Studies

Sediment Contaminants

A piston coring device equipped with a clear plexiglass tube was used to collect a one-meter core from the deepest section of the east basin. This technique permitted examination of the core to insure that the sediment-water interface was not disturbed during the coring operation. The core was extruded in 10 cm sections and placed in labelled plastic bags. All core material was kept cool at 4^{o} C until analyzed. Prior to analysis, the 0-10 cm interval was thoroughly mixed and extracted for metal and organic contaminant analyses. This upper most interval provided sufficient material for our investigation.

The metals and organics data are presented in Table 10. A total of 21 metals were analyzed with the highest concentrations being exhibited by calcium, iron, aluminum, magnesium, and manganese. All metal values were considered within the range expected for the glaciated portion of Indiana. In addition, 29 possible organic contaminants were analyzed. As with the metals, concentrations were not considered to pose any environmental threat.

Of the three basins of Koontz Lake, the east basin receives the input from the principal stream draining the watershed (Pontius Ditch) and therefore should display the highest expected concentrations for both metals and organic contaminants associated with agricultural practices. Given that none of the 50 analyzed parameters were considered to exceed permissible levels, it is most probable that the sediments throughout the remainder of Koontz Lake are free from serious chemical contamination as well.

Sediment Core Profiles

Sediment cores were collected at the deepest location of both the east and central basins (Figure 34) by means of the same piston coring device described in the previous section of this report. As always, the plexiglass tubing permitted inspection of the core to insure that the sediment-water interface was left undisturbed during the coring operation. Only those cores which we felt absolutely met this requirement were saved for analysis. The total core lengths collected from the center and east basins were 140 cm and 156 cm, respectively.

Both cores were extruded within two hours of collection. Each core was sectioned at 1 cm intervals with each sample being placed in a plastic bag for storage. All

Table 10 . Concentrations of Metals and Organic Chemical Contaminants in Surface Sediments of East Basin

METALS	ug/g dry wgt	IDEM MAX BACKGD	ORGANICS	ug/g dry wgt	IDEM MAX BACKGD
Ag	<3	<0.05	Aldrin	<0.01	0.0007
Al	19,000	9400	a-BHC	<0.01	
B	22	?	B-BHC	<0.01	0.014
Ba	158		d-BHC	<0.01	
Be	<1	0.7	Lindane	<0.01	
Ca	66,300		Chlordane	<0.02	0.029
Cd	4.8	1.0	4,4´-DDD	<0.02	
Cr	25	50	4,4´-DDE	<0.02	
Cu	63	20	4,4-DDT	<0.02	0.020
Fe	33,900	57,000	Dieldrin	<0.01	0.033
Mg	9,830		Endosulfan I	<0.02	
Mn	1,070	1,700	Endosulfan II	<0.01	
Mo	9.6		Endosulfan Sulfate	<0.05	
Na	160		Endrin	<0.01	<0.001
Ni	32	21	Endrin Aldehyde	<0.02	
Pb	68	150	Heptachlor	<0.01	0.002
Sn	<18		Heptachlor Epoxide	<0.05	
Sr	52	110	Methoxychlor	<0.20	<0.001
V	52		Toxaphene	<0.20	
Zn	122	130	PCB 1016	<0.05	
			PCB 1221	<0.05	
			PCB 1242	<0.05	0.022
			PCB 1248	0.3 <0.05	
			PCB 1254	<0.05	
			PCB 1260	<0.05	
			2,4-D	<0.67	
			2,4-DB	<0.67	
			2,4,5-T	<0.67	
			2,4,5-TP	<0.67	

samples were then kept at 4° C until analyzed. In addition to wet weight for select core levels, organic content was calculated as the difference in weight between the wet weight and that after drying at 100° C for 24 hrs. Inorganic content was calculated from the weight difference of the sample dried at 100° C for 24 hrs and ashed at 500° C for one hour. Phosphorus was determined by the standard ascorbic acid colorimetric method using filtrate collected from an HCl digestion of the sediment sample.

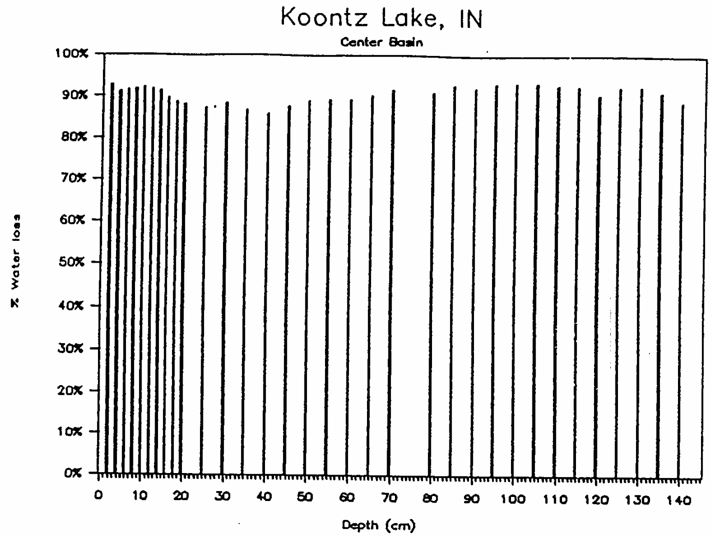
The water content of both the central basin (Figure 35) and east basin (Figure 36) cores remained above 85% throughout their profiles and displayed little change in the flocculent nature of the sediment. The surface sediment was not "soupier" than that found at depth in the core. A stratigraphic difference was noted, however, in the percent ash loss in both cores (Figures 35 and 36). Both displayed reduced ash loss in the upper 50-80 cm suggesting a recent increase in the amount of inorganic sediment reaching both basins.

The percent organic and inorganic matter profiles from both the center and east basin show pronounced stratigraphic variations. In order to better understand the significance of such patterns, we have utilized the annual sedimentation rates calculated from our bathymetric studies to assign approximate year dates to select core levels from each basin.

Sediment organic content in the center basin core at intervals lower than 90 cm were reasonably uniform and were approximately double values encountered higher in the core (Figure 37). The estimated date for this shift to much higher inorganic sediment is 1939. The organic content of the core continued to decline progressively to a depth of 20 cm (1977). Between 1977 (20 cm) and 1983 (12 cm) organic content increased slightly. It would appear that the trend towards progressively increasing inorganic sediment input established for 1939-1977, ended in 1977 with the post 1977 period being characterized by reasonably constant sedimentation rates of inorganic sediment. An overlay of organic and inorganic profiles from the center basin core clearly shows the progressive shift to increasingly inorganic sedimentation during the past 50+ years (Figure 38).

Profiles for organic and inorganic percentages in the east basin core are provided in Figure 39. As in the center basin core, the lower core levels (>104 cm) displayed generally higher organic content than levels higher in the profile. A date of approximately 1939 has been assigned the 104 cm level. Thus, in spite of the apparent imprecision of our dating estimates, both the east and central basins appear to have experienced a major increase in the

Figure 34. Sites Where Sediment Cores Were Collected in Koontz Lake



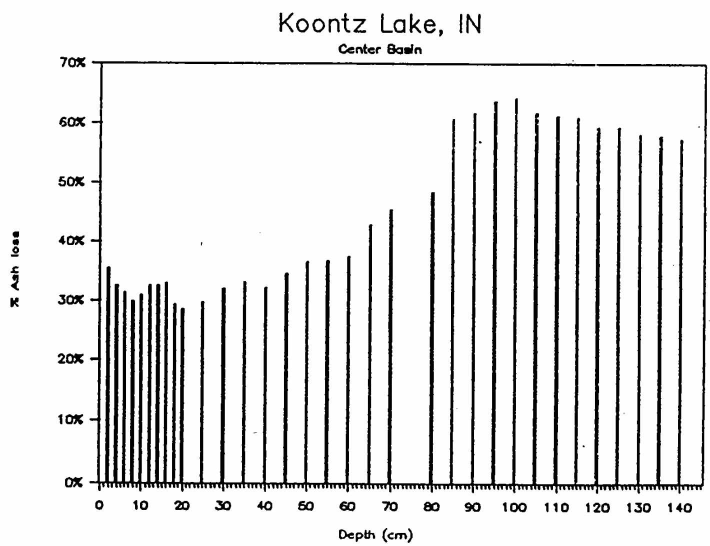
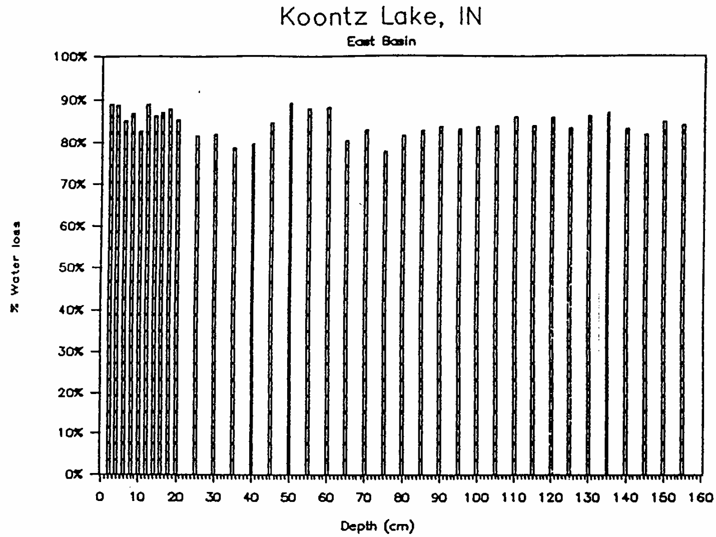


Figure 35. Water and Ash Profiles for the Sediment Core from the Center Basin of Koontz Lake



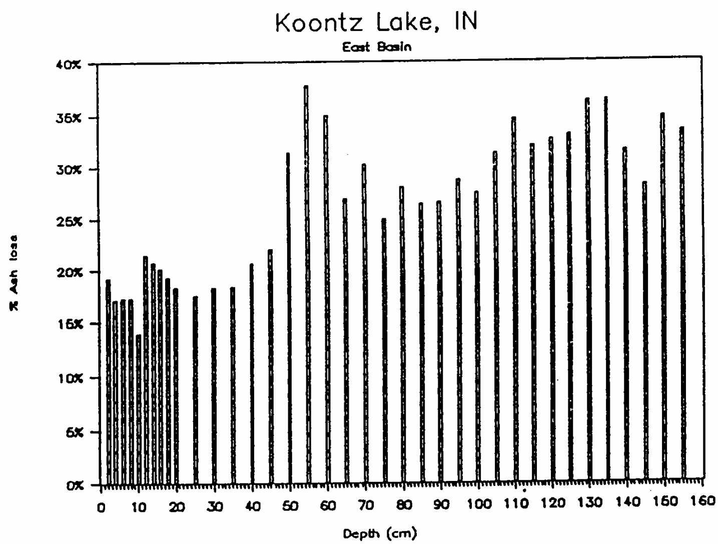


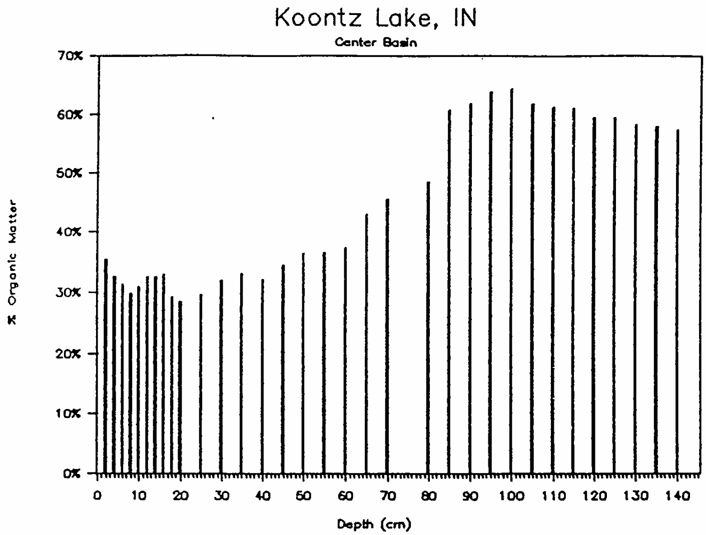
Figure 36. Water and Ash Profiles for the Sediment Core from the East Basin of Koontz Lake

rates calculated from our bathymetric studies to assign approximate year dates to select core levels from each basin.

Sediment organic content in the center basin core at intervals lower than 90 cm were reasonably uniform and were approximately double values encountered higher in the core (Figure 37). The estimated date for this shift to much higher inorganic sediment is 1939. The organic content of the core continued to decline progressively to a depth of 20 cm (1977). Between 1977 (20 cm) and 1983 (12 cm) organic content increased slightly. It would appear that the trend towards progressively increasing inorganic sediment input established for 1939-1977, ended in 1977 with the post 1977 period being characterized by reasonably constant sedimentation rates of inorganic sediment. An overlay of organic and inorganic profiles from the center basin core clearly shows the progressive shift to increasingly inorganic sedimentation during the past 50+ years (Figure 38).

Profiles for organic and inorganic percentages in the east basin core are provided in Figure 39. As in the center basin core, the lower core levels (>104 cm) displayed generally higher organic content than levels higher in the profile. A date of approximately 1939 has been assigned the 104 cm level. Thus, in spite of the apparent imprecision of our dating estimates, both the east and central basins appear to have experienced a major increase in the deposition rate of inorganic sediment in the late 1930's. Although the overall trend from 104 cm to 20 cm is towards a progressive decline in core organic content, a pulse in organic content was noted for the levels 50-60 cm. Applying our rough estimates of sedimentation rates, this period would approximate 1960-1965. A comparable pulse was absent from the central basin core. The progressive decline in sediment organic content ended in 1979 (1977 in the east basin), with values actually increasing briefly during 1979-1982 (1977-1983 in the east basin). The overlay of organic and inorganic values (Figure 40) shows that unlike the central basin which showed a reverse of sediment dominance by these two parameters after 1939 towards inorganic control, the east basin has always remained inorganic dominated throughout the period covered by the sediment core. This is not unexpected given that the east basin is smaller and thus more influenced by shoreline erosion processes and is also the most likely to be influenced by erosion products delivered from the watershed by ditches.

With the exception of a peak at 70-90 cm (1939-1948), total phosphorus concentrations in the central basin core remained relatively constant throughout the time period covered by the core (Figure 41). Phosphorus values in the east basin core (Figure 42) did not show as pronounced a



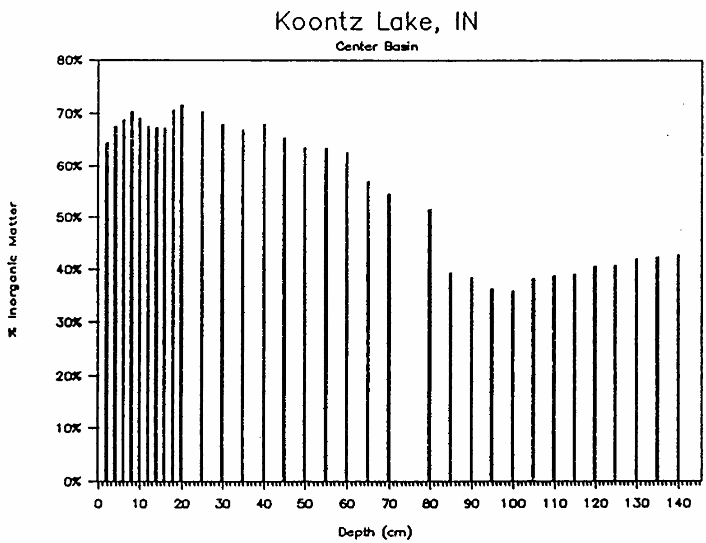


Figure 37. Profile of the Percentage Contribution of Organic and Inorganic Factions in the Center Basin Core

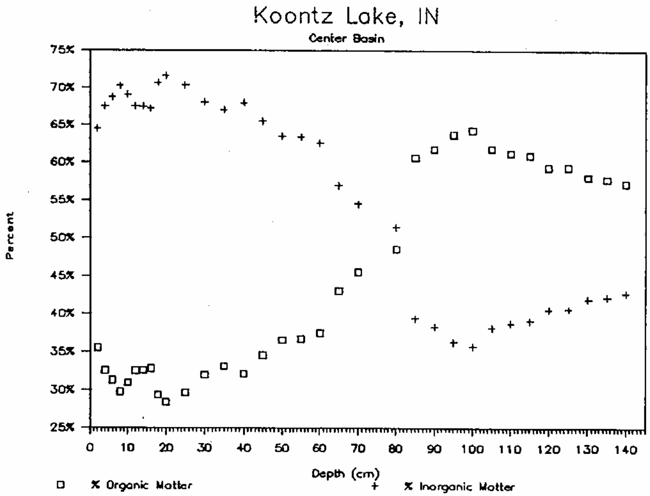
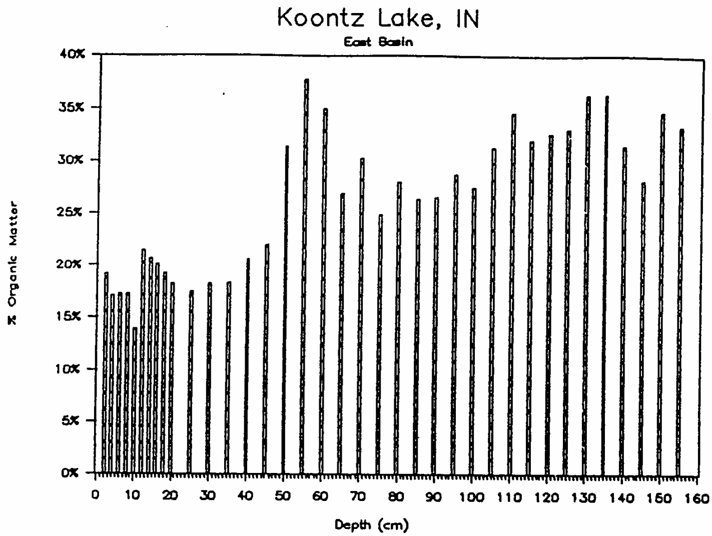


Figure 38. Overlay of Percentage Contribution of Organic and Inorganic Fractions in the Center Basin Core



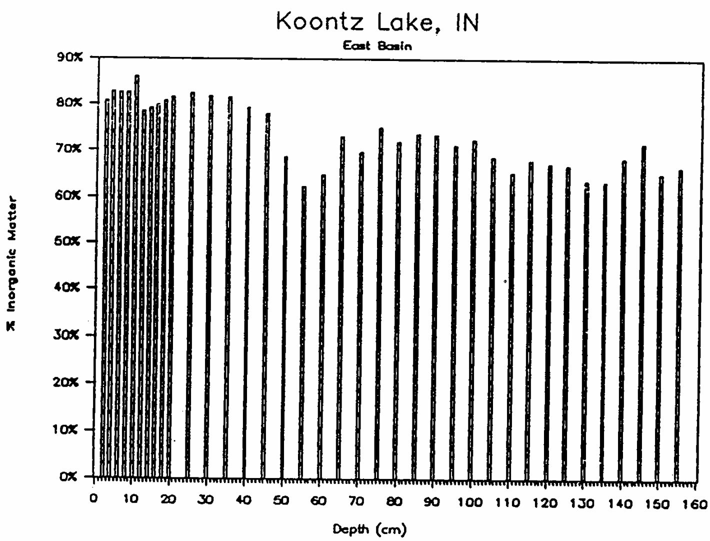


Figure 39. Profile of the Percentage Contribution of Organic and Inorganic Fractions in the East Basin Core

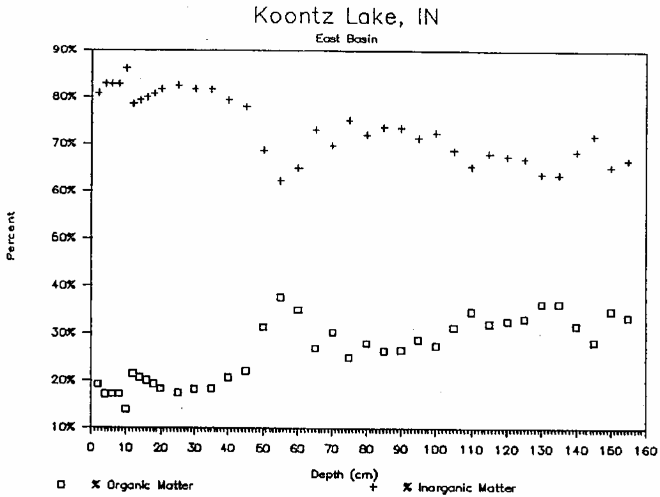
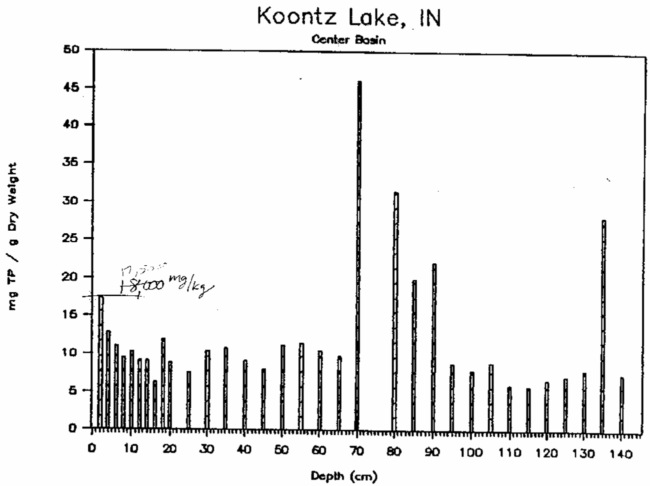


Figure 40. Overlay of Percentage Contribution of Organic and Inorganic Fractions in the East Basin Core



28.7 X background

18 mg/g × 1000g/kg

18,000

Figure 41. Profile of Total Phosphorus Concentrations in the Center Basin Core

deposition rate of inorganic sediment in the late 1930's. Although the overall trend from 104 cm to 20 cm is towards a progressive decline in core organic content, a pulse in organic content was noted for the levels 50-60 cm. Applying our rough estimates of sedimentation rates, this period would approximate 1960-1965. A comparable pulse was absent from the central basin core. The progressive decline in sediment organic content ended in 1979 (1977 in the east basin), with values actually increasing briefly during 1979-1982 (1977-1983 in the east basin). The overlay of organic and inorganic values (Figure 40) shows that unlike the central basin which showed a reverse of sediment dominance by these two parameters after 1939 towards inorganic control, the east basin has remained inorganic dominated throughout the period covered by the sediment core. This is not unexpected given that the east basin is smaller and thus more influenced by nearshore erosion processes and is also the most likely to be influenced by erosion products delivered from the watershed by ditches.

If the peak at 70-90 cm (1939-1948) is omitted, total phosphorus concentrations in the central basin core have remained relatively constant throughout the time period covered by the core (Figure 41). Phosphorus values in the east basin core (Figure 42) did not show as pronounced a range of phosphorus as displayed by the central basin. If the 70-90 cm peak from the central basin was omitted, phosphorus values from the east basin core were generally within the range seen in the central basin core profile. With the exception of 1967-1977 (45-25 cm), values during the pre 1939 period (> 104 cm) were generally lower than those of the post 1939 period in the east basin.

With the exception of the top 15 cm, sediment phosphorus concentrations in the central basin do not parallel the profile for percent organic matter (Figure 43). In fact, phosphorus concentrations displayed a pronounced peak in 1939-1948, the period of steadily declining organic content. There is a much greater correspondence of phosphorus and organic profiles for the core of the east basin (Figure 44). It is obvious that phosphorus in this basin was readily available for photosynthesis by aquatic plants or algae. These trends are further evidence that the Pontius Ditch historically always has delivered high concentrations of phosphorus leached from fields and that such nutrients were quickly tied up in vegetation of the east basin.

10,000 mg/kg

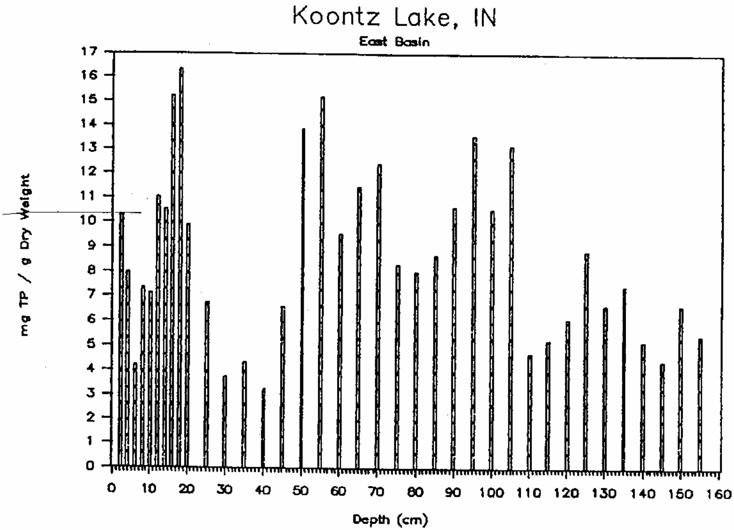


Figure 42. Profile of Total Phosphorus Concentrations in the East Basin Core

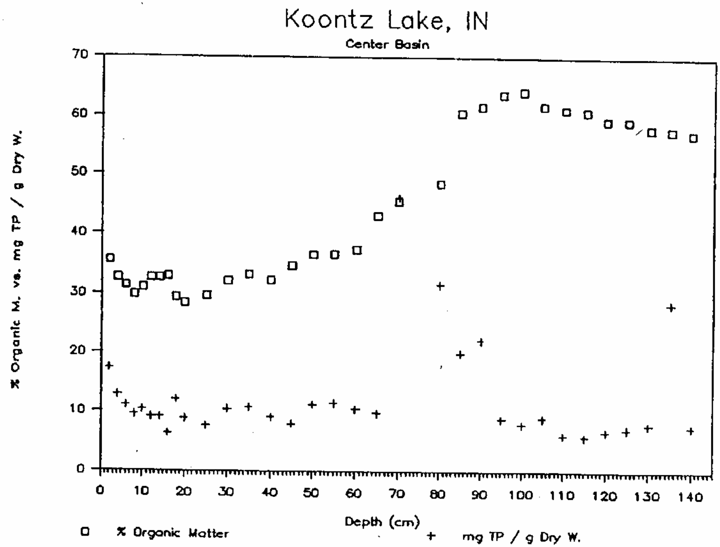


Figure 43. Profiles of Organic Matter Percent and Total Phosphorus/Gram Sediment Dry Weight for the Center Basin Core

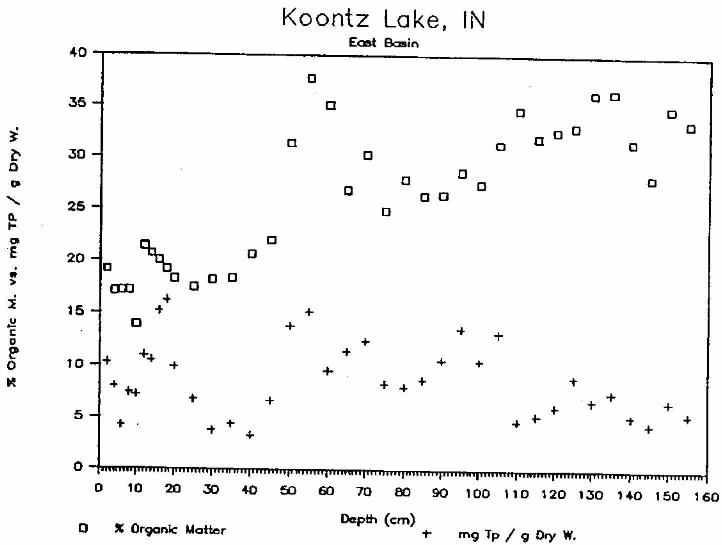


Figure 44. Profiles of Organic Matter Percent and Total Phosphorus/Gram Sediment Dry Weight for the East Basin Core

2: the Watershed.

Land Use

Several distinct types of land use exist in recent history: 1). low-moderate density residential of the Town of Koontz Lake; 2) production agriculture; and 3) small farm/residential. Soil Conservation Service aerial photographic maps from 1957 and 1972 were reviewed to determine what trends in land use should be noted. Plat maps were studied; and several individuals were interviewed. The entire watershed was visited at several times during 1987 and 1988. The Wetland Conservation Area and Natural Area to the north of the Lake buffers this small watershed area. Since some of this area is under protection and preservation, this study will not address it further other than to emphasize the great asset this area is to the lake, and that efforts should continue to preserve, protect, and acquire these important natural resources.

Only a small portion of the Town of Koontz Lake occurs within the natural watershed boundary of the Lake. The relative contribution of this area to the water quality of Koontz Lake is discussed earlier in this report.

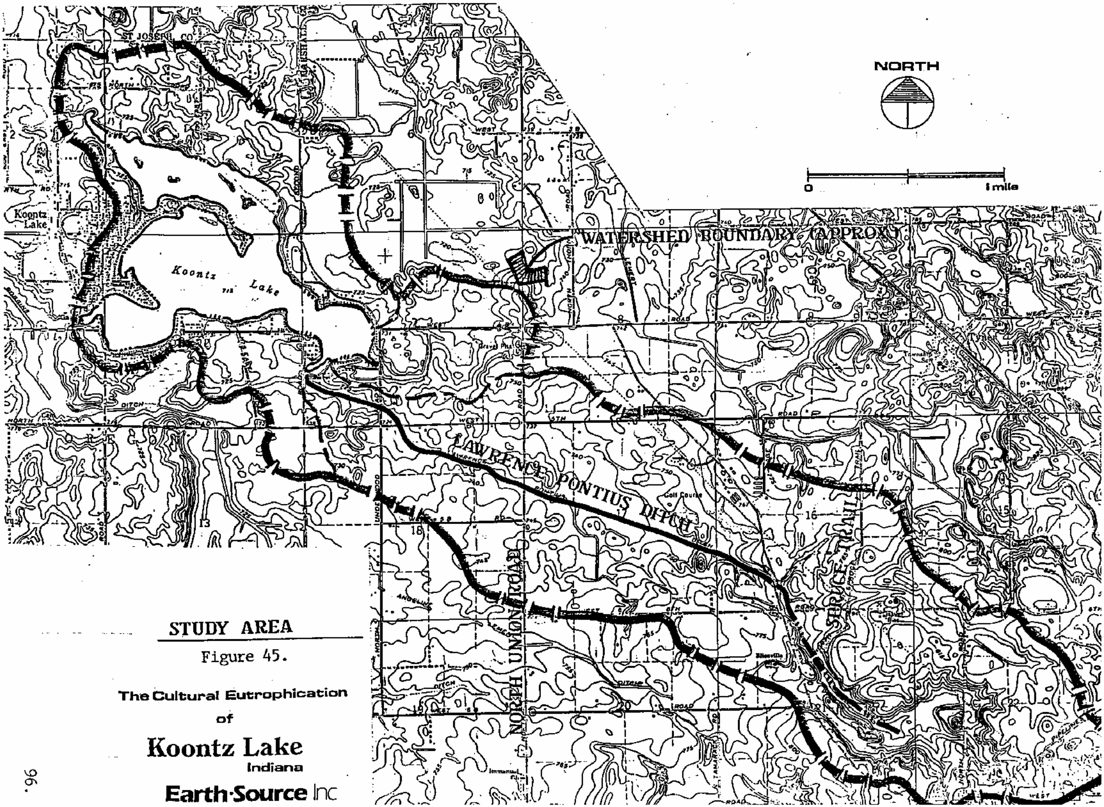
The land area involved in production agriculture remains the most significant contributor to Koontz Lake. This area consists mostly of small to medium sized tracts of land of 80 to 160 acres. Recent history seems to follow similar historical trends in agriculture. Through to the 1950's and into the mid-1960's, larger percentages of farm production were devoted to small on-farm animal production. Therefore, larger percentages of land was devoted to pasture land, hay, and grass production. The early 1970's saw a great emphasis on grain crop production, thus intensifying row crop production and tillage and, therefore, exposing some marginal lands to increased erosion. Hay and alfalfa crops were reduced from the crop rotations in this circumstance. In comparing 1957, 1972, and 1988 observations, it appears that the trend has reversed somewhat again (consistent with the general trends in agriculture) probably as a result of generally very poor economic returns for grain production and the efforts to conserve on marginal lands and soils. Several highly eroded sites noted on the 1957 maps in Sections 21, and 22 had been retired by 1972. We know of no land enrolled in the Conservation Reserve Program (CRP), although there is certainly some important opportunities. The response to our request for information about Agricultural Conservation Practices (ACP) in the Lawrence Pontius Watershed indicated that none could be recalled. Again, some potential certainly exists, particularly in the eastern third of the watershed.

Another trend in this watershed is that many smaller tracts have been added in recent year. These small farm residential tracts, usually 5 to 10 acres or less, may be a continuing trend. This has occurred mostly in the watershed near Koontz

Lake. This type of land division often removes land from crop production agriculture, but may create sedimentation problems during construction (if any). Also, the new owners may have animal operations such as horses, cattle, swine, etc; therefore, potentially contributing nutrients in that form.

The other significant land use change is the United States Golf Academy, which was developed on land that was formerly a poultry operation. This affects over 200 acres. Part of this land drains directly to the Pontius Ditch, and partly into the Burnside Ditch (tile) and then to the Pontius Ditch. The water quality from this area should be monitored in the future.

In summary, land use in the watershed is probably 'changing for the better' for the water quality of Koontz Lake. No major changes have been occurring in recent years such as major residential, industrial or commercial developments. Woodlands and grasslands seem to have stabilized or increased. Continuing cooperation by land owners to control erosion should be sought. Opportunities should be taken advantage. If problems are observed or become apparent during water quality monitoring, the sources should be addressed immediately. Although important progress is being made by this report and construction on the Pontius Ditch, continuing the awareness to protect the Lake is vital. Careless land use, erosion, or a major future change in the watershed may override the benefits of the corrective measures.



STUDY AREA

Figure 45.

The Cultural Eutrophication

of

Koontz Lake

Indiana

Earth·Source Inc

Highly Erodible Land (HEL) - see map

The purpose of this illustration is to display the fabric of fragile lands so that the study may target the areas of general concern. Using the Soil Survey of Marshall County by the USDA-SCS issued 1980, and data provided by the local SCS office, soils in the HEL designation were mapped.

The following soils occur within the study area and have been highlighted:

ChC - Chelsea fine sand, 6 to 12% slopes.
MgC - Metea loamy fine sand, 6 to 12
OsD - Oshtemo loamy sand, 12 to 18
PsC; PsD - Plainfield Sand; 3 to 10, & 12 to 18
RsC2; RsD - Riddles sandy loam; 6 to 12, & 12 to 18
WkC2; WmD3 - Wawasee sandy loam, 6 to 12, & 12 to 18

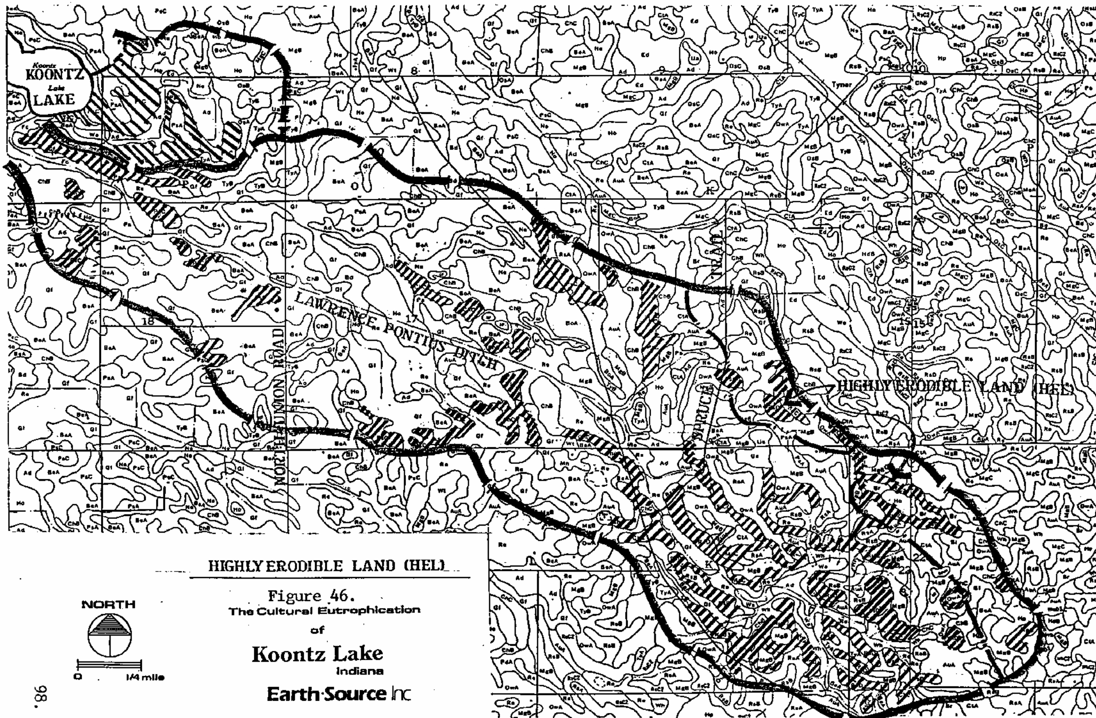
A majority of the HEL is in the upper third of the watershed as can be seen on the map. Of the entire 4.4 square mile Lawrence Pontius (2800 acre) watershed, approximately 420 acres are mapped as HEL. Of this total about 90 percent are considered to be directly contributing to the Lawrence Pontius Ditch and Koontz Lake.

Slope Study

Using USGS topography, a map was generated indicating slopes in excess of 10%. This is also an illustration of length of steep slopes. This map enhances the location of Highly Erodible Land and further illustrates the areas of greater erosion concern.

The map shows that most of those slopes occur in the upper third of the Lawrence Pontius watershed above Spruce Trail. In addition, the discovery is that most of the runoff from these slopes contribute directly into the Lawrence Pontius water way. Only a small portion at the extreme eastern edge of the study area will runoff into upland depressions, and is therefore less or non-contributing to the nutrient/sediment loading in the watershed. Remaining upland depressions are important to controlling the speed of flow through the Lawrence Pontius system and should be preserved.

The highest elevation in the watershed at the extreme east end is 850'+. A total fall exists of over 125' to the lake level of 714.56 in a distance of approximately 4.8 miles.



HIGHLY ERODIBLE LAND (HEL)

Figure 46.
The Cultural Eutrophication
of
Koontz Lake
Indiana

Earth·Source Inc

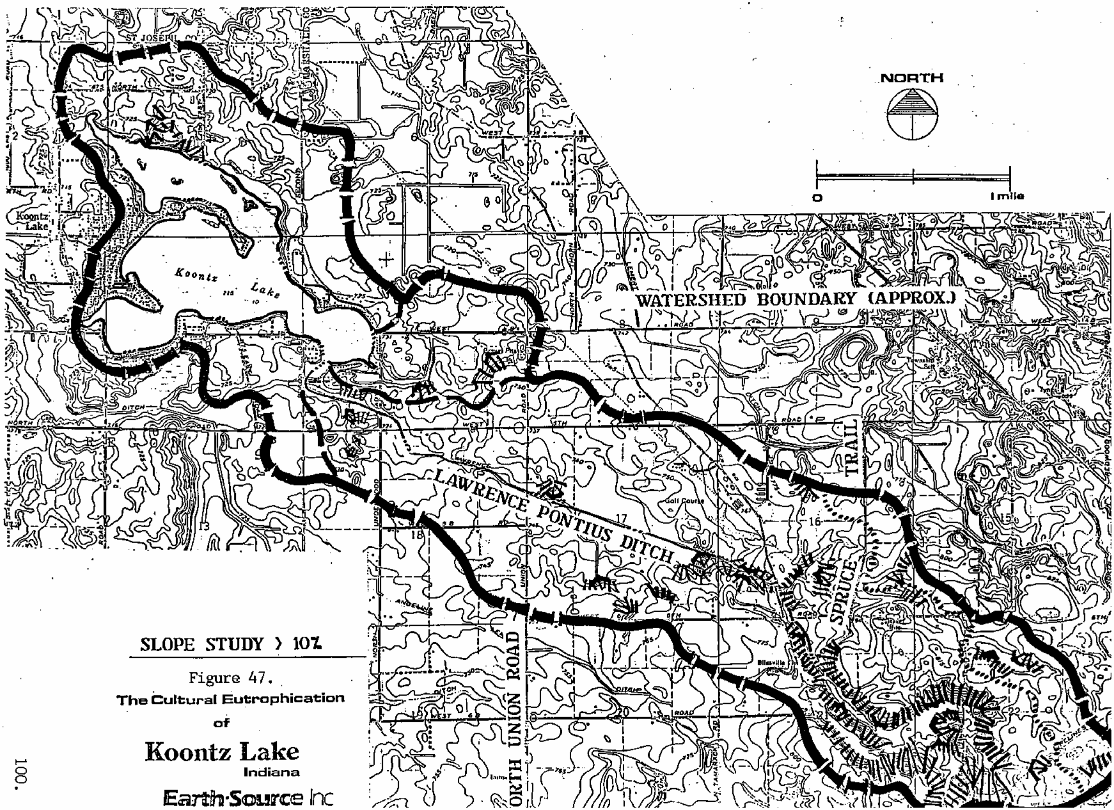
'86

SOIL LEGEND

Map symbols consist of a combination of letters or of letters and numbers. The first capital letter is the initial one of the map unit name. The lowercase letter that follows separates map units having names that begin with the same letter, except that it does not separate sloping or eroded phases. The second capital letter indicates the class of slope. Symbols without a slope letter are for nearly level soils or miscellaneous areas. A final number of 2 indicates that the soil is eroded and 3 that it is severely eroded.

SYMBOL	NAME
Ad	Adrian muck, drained
AuA	Aubbeenaubbee sandy loam, 0 to 2 percent slopes
Bd	Brady sandy loam
BeA	Brems sand, 0 to 2 percent slopes
BoA	Bronson loamy sand, 0 to 2 percent slopes
Br	Brookston loam
ChB	Chelsea fine sand, 2 to 6 percent slopes
ChC	Chelsea fine sand, 6 to 12 percent slopes
CtA	Crosier loam, 0 to 2 percent slopes
Ed	Edwards muck, drained
EsA	Elston sandy loam, 0 to 2 percent slopes
Fc	Fluvaquents, loamy
FsA	Fox sandy loam, 0 to 2 percent slopes
FsB	Fox sandy loam, 2 to 6 percent slopes
FsC2	Fox sandy loam, 6 to 12 percent slopes, eroded
Gf	Gilford sandy loam
HdB	Hillsdale sandy loam, 2 to 6 percent slopes
Ho	Houghton muck, drained
Hp	Houghton muck, ponded
LnA	Linkville sandy loam, 0 to 2 percent slopes
LnB	Linkville sandy loam, 2 to 6 percent slopes
MeA	Martinsville loam, 0 to 2 percent slopes
MeB	Martinsville loam, 2 to 6 percent slopes
MeC2	Martinsville loam, 6 to 12 percent slopes, eroded
MgB	Metea loamy fine sand, 2 to 6 percent slopes
MgC	Metea loamy fine sand, 6 to 12 percent slopes
Mn	Milford silty clay loam
Ne	Newton loamy fine sand
OsA	Oshtemo loamy sand, 0 to 2 percent slopes
OsB	Oshtemo loamy sand, 2 to 6 percent slopes
OsC	Oshtemo loamy sand, 6 to 12 percent slopes
OsD	Oshtemo loamy sand, 12 to 18 percent slopes
OwA	Owosso sandy loam, 0 to 2 percent slopes
Pa	Palms muck, drained
PdA	Pinhook sandy loam, 0 to 2 percent slopes
PsA	Plainfield sand, 0 to 2 percent slopes
PsC	Plainfield sand, 3 to 10 percent slopes
PsD	Plainfield sand, 12 to 18 percent slopes
Re	Rensselaer loam
RsA	Riddles sandy loam, 0 to 2 percent slopes
RsB	Riddles sandy loam, 2 to 6 percent slopes
RsC2	Riddles sandy loam, 6 to 12 percent slopes, eroded
RsD	Riddles sandy loam, 12 to 18 percent slopes
SpA	Shipshe sandy loam, 0 to 2 percent slopes
St	Stonelick sandy loam
Tx	Troxel silt loam
TyA	Tyner loamy sand, 0 to 2 percent slopes
TyB	Tyner loamy sand, 2 to 6 percent slopes
TyC	Tyner loamy sand, 6 to 12 percent slopes
Ua	Udorthents, loamy
Wa	Wallkill loam
Wh	Washtenaw silt loam
WkB	Wawasee sandy loam, 2 to 6 percent slopes
WkC2	Wawasee sandy loam, 6 to 12 percent slopes, eroded
WmD3	Wawasee sandy clay loam, 12 to 18 percent slopes, severely eroded
Wt	Whitaker loam

Table 11.



SLOPE STUDY > 10%

Figure 47.

The Cultural Eutrophication

of

Koontz Lake

Indiana

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Potential Target Sites for Nutrient & Sediment Trapping

Independent of work being produced by the DNR Division of Water, and Division of Soil Conservation, several sites are suggested for nutrient and sediment trapping in the Lawrence Pontius watershed. This study is limited in depth, following the scope of services for this particular report. The State is involved in an extensive project of drop structures in the ditch (for sediment trapping); and a constructed wetland (for sediment and nutrient trapping) is in progress as prepared through the DNR Division of Water.

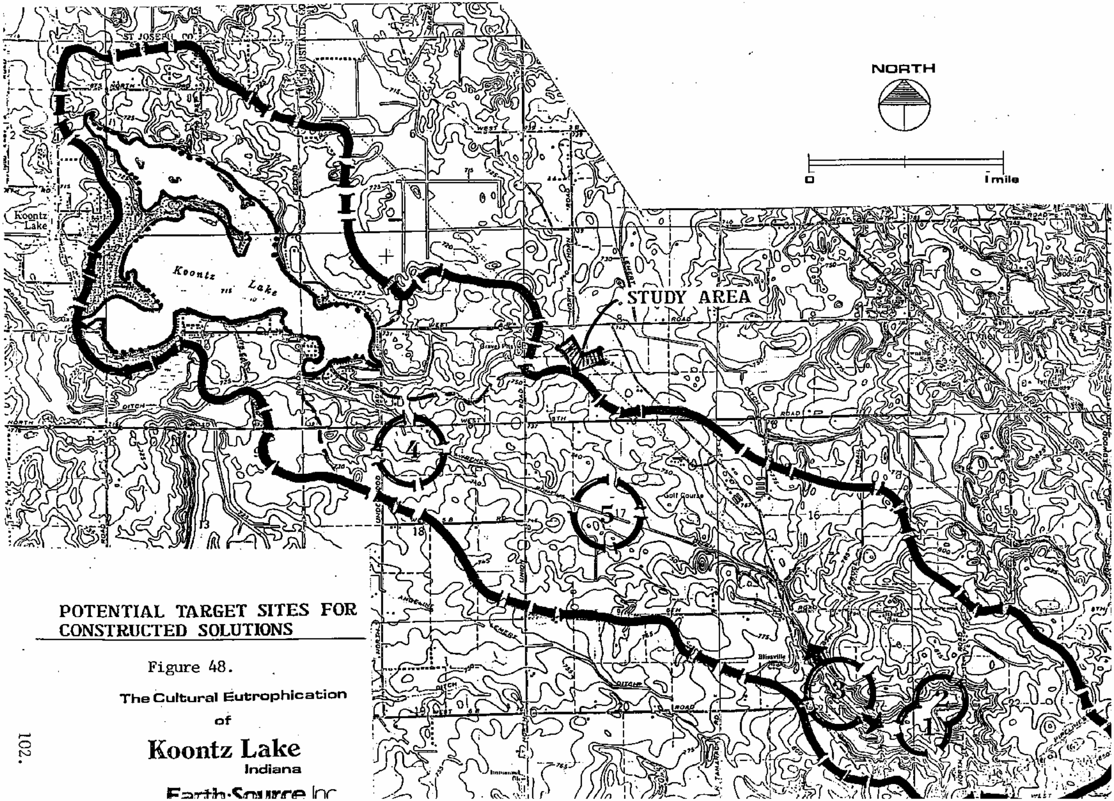
The criteria for target site selection is essentially to locate a site either near the bottom of the watershed, where it provides immediate protection to the lake and the entire watershed must pass through; or, in the upper end of the waterway as near to the problem source as possible.

As stated before, the significant portion of HEL soil types are above Spruce Trail in the Lawrence Pontius watershed. Natural and cropland erosion are both of concern from this area. Some of these soils remain in row crop production with perhaps the most dramatic example of cropland erosion at the northwest corner of North Rose Road and the Plymouth-Walkerton Trail. This particular site should be retired from agricultural production. Other areas observed are currently in alfalfa production or pasture. Various opportunities exist for conservation practices such as grassed waterways and terraces.

Four target sites are identified on the map, plus a potential fifth site near the center of the watershed. Sites 1, 2, and 3 address trapping in the upper watershed. Site 4 is the area currently under design development in the lower watershed. Sites 1, 2, and 3 contain substantially hydric soils that may have historically been upland marshes. Some trapping ability exists at these sites now, but, upon closer inspection, they are channelized. This is also an area of open and sub-surface drainage. The high amount of relief above sites 1, 2, and 3 should easily allow for construction without adversely affecting upland drainage.

Another potential area that may be targeted is adjacent to the United States Golf Academy golf courses. Topography and hydric soils in this central area suggest that an opportunity may exist here. The golf course area of the Lawrence Pontius Ditch, should be monitored for water quality, since golf courses are notoriously known as nutrient-loading sources. This site is indicated as site 5.

In summary, several sites have apparent potential for addressing water quality improvement to the Lawrence Pontius Ditch, and therefore to Koontz Lake. Some further study by the Koontz Lake Environmental Enhancement Committee, Inc.,



POTENTIAL TARGET SITES FOR CONSTRUCTED SOLUTIONS

Figure 48.

The Cultural Eutrophication of

Koontz Lake
Indiana

Earth Source Inc

could include water quality study, conceptual design development for constructed solutions, and cost estimating. These items are beyond the scope of this study. Also, government agencies should be made aware of the desire of the K.L.E.E.C. to focus attention on the watershed areas of concern that are highlighted in this limited study. This attention may suggest various upland constructed solutions, land retirement, or minimum/no-till farming practices, etc.

3:Summary; Recommendations; Conclusions.

Summary; Recommendations; and Conclusions

The Lake

Water Quality

The general water quality of Koontz Lake appears to have changed little since at least 1965. The lake has routinely experienced severe oxygen depletion during summer for all areas greater than 10 feet deep. The 1988 values for most physical and chemical parameters including total phosphorus and chlorophyll were within the range recorded for earlier years, and the mean lake eutrophication index values for 1975 (42) and 1988 (37) were comparable. During 1988, the best overall water quality was found in the central basin followed by the west and east basins, respectively.

It is clear that Pontius Ditch has a pronounced effect on water quality in Koontz Lake. The worst water quality of Koontz Lake is recorded in the east basin, the entry point for Pontius Ditch. Between 1965 and 1975, the carbonate content of Koontz Lake water increased progressively. Such a carbonate enhancement is most likely the result of increased field liming and/or erosion and the delivery of excess carbonates to the lake via Pontius Ditch. It is interesting to note that DNR did not report aquatic weed problems in the lake until 1965, the beginning of the carbonate enrichment period. Expansion of the weed infestation continued to parallel the increased enrichment of the carbonate concentration of Koontz Lake water throughout the 1970's. Elsewhere in the Midwest, it is generally accepted that the abundance of aquatic weeds is reasonably correlated with the carbonate content of lake water.

The 1988 survey clearly demonstrated the expected response of water quality to a reduction in the influence of Pontius Ditch. The drought of 1988 reduced not only the flow of Pontius Ditch but also its contribution of nutrients to Koontz Lake. The immediate result was a marked increase in water clarity reflecting an overall reduction in the abundance of algae in the water column. Water clarity in Koontz Lake was better than any time since at least 1965 and was approximately 25-35% greater than "normal" values. A similar trend was also noted for Lake Maxinkuckee during 1988 associated with a major reduction in stream input of nutrients.

While one can not discount the fact that septic tanks at shoreline residences are also contributing to the general eutrophication of Koontz Lake, it is obvious that if the input of nutrients from Pontius Ditch is reduced significantly, water quality in Koontz Lake can be expected to improve markedly in both the short and long term.

Bacteria

Surveys indicated major bacterial contamination of Koontz Lake during the 1950's and 1960's from inadequate treatment of human sewage via septic tanks and possible animal waste products delivered via Pontius Ditch. After extensive state supervised corrective actions, fecal contamination of Koontz Lake has been well within state standards since 1971. While the present septic disposal of human wastes does not pose a serious health problem for water contact sports, it is likely that nutrients are leaching from individual drain fields and contributing to the general eutrophication of Koontz Lake.

Algae

Since as early as 1975, and likely much earlier, blue-green algae have dominated the algal assemblage of Koontz Lake. Such algal assemblages are considered indicative of advancing eutrophication and can pose serious management problems if they become excessively abundant. Problems encountered in other Midwest lakes include windrows of decaying algae along shores with associated odor problems and both fish kills and "swimmers itch" or other skin rashes on bathers resulting from toxins produced by some species of blue-green algae. While Koontz Lake has not experienced such severe manifestations associated with blue-green algae, both a further degradation in water quality and/or excessive control of aquatic weeds may upset the current ecological balance to favor a major enhancement of blue-green algal abundance. Once a lake becomes algal dominated, management problems are compounded and the likelihood of restoring a balance between algae and weeds is greatly diminished.

Macrophytes

Aquatic weeds were first suggested as a potential management problem by the DNR in 1965. Although several long term lake residents have suggested that major fluctuations in macrophytes occurred prior to this date, it is most unfortunate that 1965 represents the first time that the weed problem was documented by any state agency. The overall extent of the weed infestation increased progressively throughout the late 1960's and early 1970's so that by 1974, the DNR considered all areas of the lake $<$ 8 feet to be seriously infested with aquatic weeds and suggested implementation of an aquatic weed control program.

Although the species composition of the plant community has not changed markedly, the aquatic weed infestation has continued to expand so that during 1988 the water column under approximately 23% of the surface area of Koontz Lake is considered to be 100% filled with aquatic weed growth. The problem is most pronounced in the east basin where approximately 54% of the basin displays 80-100% weed infestation of the water column. Only 28% and 25% of the center and west basins, respectively, are considered comparably infested with weeds.

The major problem plant in all three basins of Koontz Lake is coontail (Ceratophyllum). Within the east basin, the overall extent and general richness of growth for coontail increase with increasing proximity to the inlet of Pontius Ditch into the basin. It is obvious that the growth of coontail is directly related to proximity to nutrients being delivered by Pontius Ditch. It is likely that this plant is acting as a biological trap for stream-delivered nutrients, thus minimizing the eutrophication impact of such nutrients elsewhere in Koontz Lake.

In addition to reducing weed biomass during early summer, the chemical control program along the northern shore of the east basin during 1988 also affected plant composition later in the growing season. Although the plant biomass in the controlled area was somewhat less than untreated areas of the basin during July 1988, coontail was effectively replaced by several species of pondweeds. Such a species replacement is considered beneficial to both fish and waterfowl.

As stated earlier, initial documentation of the aquatic weed problem by the DNR occurred in 1965 and its subsequent proliferation coincided with a period of increasing carbonate delivery to Koontz Lake presumably by Pontius Ditch. The likely source of the increased watershed export of carbonate may rest with an alteration in field liming practices or enhanced runoff of erosion products. A second factor for the spread of aquatic plants suggested by DNR is the loss of carp following the 1970 fishery renovation. It was suggested that carp stir bottom sediments during feeding thus increasing turbidity to shade out weeds. Following carp removal, plants were no longer limited by carp induced shading. While plausible in part, the scenario fails to fully explain the expansion of weeds that occurred before carp removal. A third and major factor in the spread of aquatic weeds is the increased availability of appropriate habitat. While the aerial extent of the 0-5 foot contour in all three basins doubled in the last 33 years, the extent of the 5-10 foot contour during the same period was reduced approximately 50% in the west and central basins and an alarming 86% in the east basin. Sediment in these basins is clearly being eroded from shallow areas and being redeposited farther offshore. The end result of such shoaling is that a progressively increasing percentage of the lake bottom in the past 33 years lies close to the Secchi depth transparency level (5 feet) and thus within a zone in which macrophytes can have sufficient light to photosynthesize and grow. While excluded from the deepest areas because of insufficient light, plants have been able to colonize these increasingly available shallow areas to a point where they are now perceived as a major management problem. The plant problem in Koontz Lake may not be so much of a vertical expansion of plant growth from the depths to the lake surface as a creation of new habitat for plant colonization due to near shore erosion and resulting off shore shoaling. Such an interpretation is supported by the fact that underwater plant stands are rarely over 4 feet tall in Koontz Lake even in areas of greatest infestation.

Fish

While the DNR considered bluegill and largemouth bass populations in Koontz Lake during 1955 to be good to excellent, their 1965 survey indicated that the fishing had deteriorated to a point where it was considered of little value to anglers. The quality of the fishing had further degraded to a point by 1969 that DNR proposed a total fishing renovation for the lake. Renovation and restocking took place during 1970-71. As early as 1973 gamefish comprised 73% of total fish abundance, and this percentage increased progressively thereafter with the 1983 fish survey demonstrating 87% gamefish.

While total gamefish abundance increased progressively following fishery renovation, the fitness of the population did not. The assemblage was dominated by abundant individuals of poor quality for recreational fishing. In part this was a reflection of a progressive expansion in the extent of aquatic weeds after 1965. Excessive weeds protected young fish from predators and insured greater survivability of individuals of the same year class. On the other hand, excessive weeds meant increased difficulty finding sufficient food to support such elevated fish population levels.

The second explanation for the observed gamefish changes is a loss of predators. In order to increase the fitness of the gamefish populations, DNR began stocking northern pike in the early 1970's and established a 14-inch limit for largemouth bass on 1 October 1984. Subsequent survey results suggested that bass reproductive success has been enhanced by the 14-inch size limit, but the long term effects on predator-prey interactions requires additional surveys to track the bass population.

Basin Infilling

Our core studies indicate that stream delivery of inorganic sediment increased markedly approximately 1939 and increased progressively until about 1977-1979. Sediments deposited after 1977-1979 were less dominated by inorganics than before suggesting an acceleration in the degree of eutrophication during the past 10 years.

Pontius Ditch has clearly been the major source for sediment entering Koontz Lake. Since 1955, a major delta has formed where this ditch enters the east basin, and it has been colonized by a dense cover of cattails, grasses and water lilies. While causing extensive basin infilling in the east basin, it is likely that a great deal of sediment from this source has been deposited throughout the Koontz Lake system. In addition to watershed erosion materials delivered by Pontius Ditch, shoaling of offshore areas formerly 5-10 feet deep has occurred in basins as the result of nearshore erosion via wave action. Unlike typical lake deposition patterns, all basins appear to be infilling from the shore toward their centers. Since 1955, all have experienced a doubling in the area of the 0-5 feet water depth zone along their shorelines. Sediment entering Koontz Lake via Pontius Ditch would travel through the central and west basins on its way to the lake outlet and would be expected to be deposited differentially in these basins, especially in the deepest areas. Only wave action can be used to explain the fact that all three basins, especially the two smallest, are experiencing massive infilling from the shore toward the center.

The source of the enhanced wave action since 1955 is obvious. In pristine lakes, waves are generated only during storm events and thus occur only intermittently for brief periods. With the advent of the modern speed boat, shorelines are pounded incessantly during the summer recreational season by wave intensities normally seen only during the most severe storms. The erosive action of such waves on nearshore areas is extreme and in heavily developed lakes, such as Koontz, magnified by the removal of nearshore emergent vegetation by homeowners. The impact of speed boats on water clarity has been well documented by our investigations on Lake Maxinkuckee. Boat traffic on the Fourth of July holiday stirred enough inorganic sediment into the water column to reduce Secchi transparency by 50%, while sediment suspended by waves from typical summer weekend boating activity kept water cloudy until the middle of the following week. One need only go to Koontz Lake on any summer weekend to observe the identical effects. As Koontz is much smaller than Maxinkuckee, it is likely that nearshore erosion and offshore shoaling even more serious there.

As stated earlier, such shoaling has produced new habitat for aquatic weeds. A majority of the underwater plant growth in Koontz Lake is < 4 feet tall even in the most severely infested areas. It is suggested that a great deal of the expanding plant infestation that has spread progressively since 1965 is the result of new habitat created when speed boat generated waves promote nearshore erosion and offshore shoaling rather than expansion of deep water plants vertically to fill the water column in direct response to increased delivery of nutrients from the watershed.

Recommendations

Stream Inputs of Nutrients and Sediments

As demonstrated by the 1988 survey, reduction in the nutrient and sediment loading from Pontius Ditch will result in a pronounced improvement in water quality. In addition to possible watershed control measures, it is suggested that aquatic vegetation colonizing the delta found at the mouth of Pontius Ditch as well as the extensive coontail beds immediately in front of the delta in the east basin both act as in-lake kidneys to trap nutrients delivered by the ditch, thus making them less available to blue-green algae. Tying nutrients up into plant tissue is always preferable to algal biomass especially in lakes like Koontz, where potentially nuisance producing blue-green algal taxa are already abundant and likely to expand into a serious management problem if supplied with additional nutrients. Therefore, it is recommended that the delta and its plant communities be left intact until such time as controls have been implemented that effectively trap nutrients and sediments within the watershed before they can enter the lake.

Specifically, large scale dredging should not be considered. Such action is likely to release nutrients into the east basin to further degrade water quality and promote massive algal blooms. It is feasible, however, to consider cosmetic dredging along the shore to insure that homeowners trapped by the delta formation can get their boats to open water. If undertaken, turbidity curtains must be employed and spoil material must be removed from nearshore areas to insure that nutrients will not be released back into the lake.

The cattail and grass marsh that has developed on the delta must be left intact so that it can act as a kidney to trap nutrients and sediments delivered by Pontius Ditch. The same applies to the extensive coontail growth immediately in front of the delta.

Basin Infilling

The volume of Koontz Lake is being progressively reduced by inorganic sediments delivered by Pontius Ditch. It is recommended that the current delta at the mouth of Pontius Ditch be retained as an in-lake sediment and nutrient trap. Dredging of this area should be limited to only those areas where homeowners can no longer get their boats to the open water of the lake. Even then, only extremely narrow channels as close to the shore as possible should be permitted.

Aquatic weeds act both to stabilize the delta and to trap nutrients being delivered via Pontius Ditch. The cattail marsh that has developed on the delta should be left in tact to maximize the kidney effect of this plant community.

Erosion form nearshore areas via waves generated from speed boats is also leading to infilling of deep water areas and shoaling of nearshore areas. It is recommended that homeowners be encouraged to leave a fringe of emergent grasses along the entire length of their lake front that extends as far as possible into the lake. Clearing of this weed zone should be limited only to dock areas and access channels for boats to enter open water. Such weed beds reduce wave action and lessen nearshore erosion. Homeowners should also be encouraged to inspect their shoreline regularly for evidence of erosion and to correct it immediately. Finally, it is recommended that speed boats be totally restricted from operating in the east and west basins. These two basins are so small that boat-generated waves can do severe nearshore damage. Even within the central basin, it is recommended that speed boats and water skiing be limited to the offshore areas. We suggest establishing a 200-400 foot shoreline zone marked by buoys within which only minimum speeds are permitted. It is also obvious that Koontz Lake has reached its limit on the number of speed boats that can operate safely during peak use periods. It is suggested that the residents explore ways to establish an upper limit on the number of boats permitted to operate simultaneously on the lake. This will help minimize wave action.

Aquatic Weeds

It is essential that no major program of aquatic weed control be implemented until the nutrient and sediment inputs from Pontius Ditch are drastically reduced or stopped. If weeds are too severely reduced, the kidney effect of the weed beds will be curtailed and nutrients entering the lake will then be available for promoting massive algal blooms. In addition, if the dead weeds are left in the lake, they will release massive quantities of nutrients during decay, thus adding to the potential seriousness of algal blooms. Once algae dominate a lake, weed beds are totally shaded out and restoration of the lake to a balanced ecosystem of great recreational value becomes extremely costly and may not even be feasible. Koontz Lake already has an abundant algal community that is dominated by blue-green algal species known to cause major management problems in other Midwest lakes when supplied with sufficient nutrients. Fortunately for Koontz Lake, the weeds trap nutrients and thus compete with algae. If weeds are eliminated, algal problems will appear immediately, and lake management costs will skyrocket.

It is recommended that weed control measures be limited to the immediate vicinity of dock areas. Based on our 1988 investigations, it appears that chemical control will replace nuisance coontail with pondweeds considered to have enhanced wildlife value. Under no circumstances should weed control be practiced near the delta in the east basin or in the constricted areas between individual basins of the lake. The latter areas receive the brunt of speed boat waves. Use of distribution maps provided in this report will help to identify areas of the lake with potential weed control needs.

Fisheries

It appears that the 14-inch size limit placed on largemouth bass will likely improve the overall quality of the gamefish populations by insuring sufficient predators to cull out the least fit individuals. It is recommended that this size limit remain for Koontz Lake until such time that the gamefish fitness improves markedly. Likewise, the success of northern pike introductions has been good, and the DNR should be encouraged to continue stocking of major predator fish. Overall, the DNR has done an excellent job managing the Koontz Lake fishery in spite of severe limitations in both funding and manpower. It is recommended that residents encourage the State of Indiana to provide additional funding support for the type of service offered by DNR.

Individual Actions

There are a number of things that individual lake residents can do to help reverse the eutrophication of Koontz Lake. Those residents immediately along the shore should cease fertilization of their lawns. Most of these nutrients are readily leached into the lake and promote weed and algal growth. Simple irrigation of lawns using lake water will provide sufficient nutrients to sustain lawn growth. Because drain fields for most residents are likely to be immediately above or in the zone of water saturated soils, proper maintenance of septic tanks and drain fields is essential to minimize leaching of nutrients into the lake. While sewage effluent currently appears to be a minor source of the eutrophication of Koontz Lake as compared with the contribution from Pontius Ditch, it will become increasingly important as watershed sources are identified and corrected. Thus, it is essential to maintain proper sewage disposal now. Phosphate-free detergents should be used both for clothes and dishes. As most of the waste water from such practices enters the nearshore water saturated zone and can eventually enter the lake, simple product modification may significantly reduce nutrient loading to the lake from this source.

Summary; Recommendations; Conclusions.

The Watershed:

1. Preserve upland depressions to reduce flow rates through the watershed.

2. Monitor several stations in the Pontius Ditch to determine if there are sources of nutrients and sediments and where they occur.

3. If warranted by these tests, investigate the use of sites 1,2,3, and 5 for constructed nutrient/sediment control. (see map)

4. Investigate, and encourage removing additional Highly Erodible Land from cropping. (see map)

5. Be aware of the need for continuing diligence in dealing with controllable and unnecessary soil and water pollution throughout the watershed , including the town of Koontz Lake.

6. Preserve natural areas that buffer the lake from surrounding uplands.

7. Encourage minimum and no-till farming throughout the watershed. Note that although water erosion and water suspended solids have been a principal concern, that many of the soils types in this watershed are easily displaced by wind erosion. Some of these blown soils drift into ditches or are otherwise more easily suspended.

8. The contributing factors to the decline of water quality and sedimentation are multiple. Some of these are being addressed by construction in progress or planned in the Pontius watershed. However, these solutions may become ineffective if there are major changes or decline in land stewardship in the watershed.

9. Encourage separation of large animal operations away from the waterways.

10. The sandy loam soils of the HEL in the watershed should be able to be successfully treated by sediment trapping. The delta being formed in Koontz Lake is further evidence that a substantial percentage of the sediment will "drop out" in similar circumstances. In order to achieve nutrient removal (targeting phosphorus and nitrogen, which are tied in a larger percentage to clay particles), additional retention time and filtering is necessary. Therefore, recommending the use of constructed wetlands in combination with a sediment trap will be a most effective solution.

Appendix.

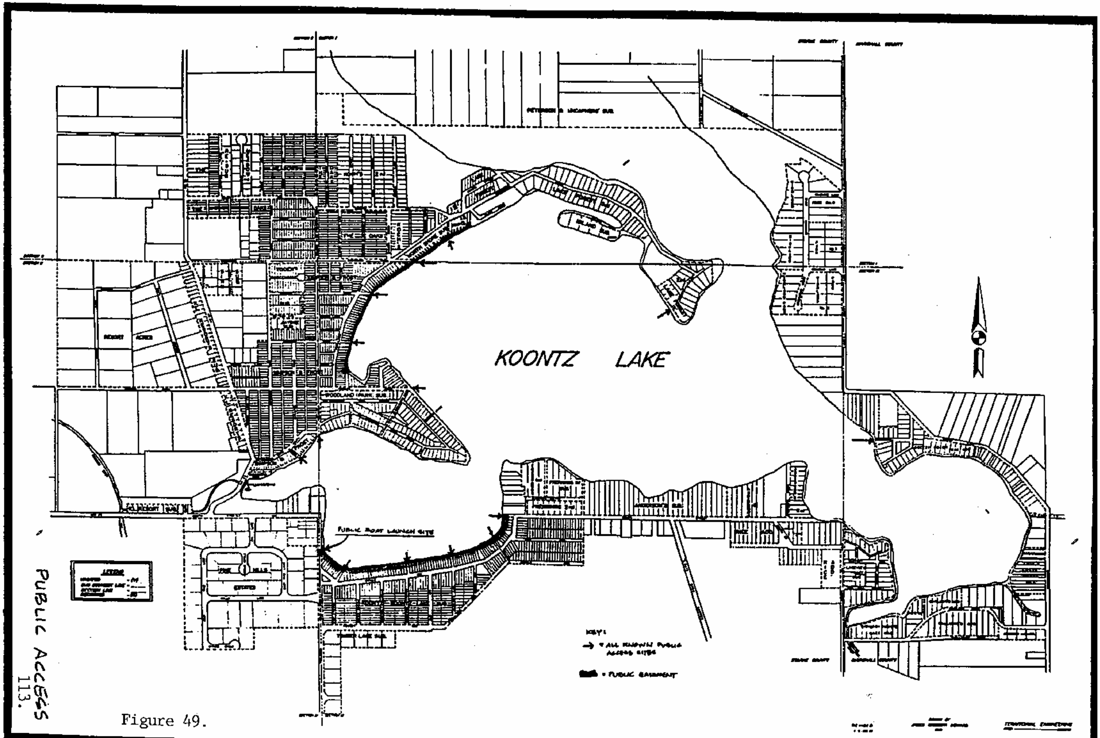
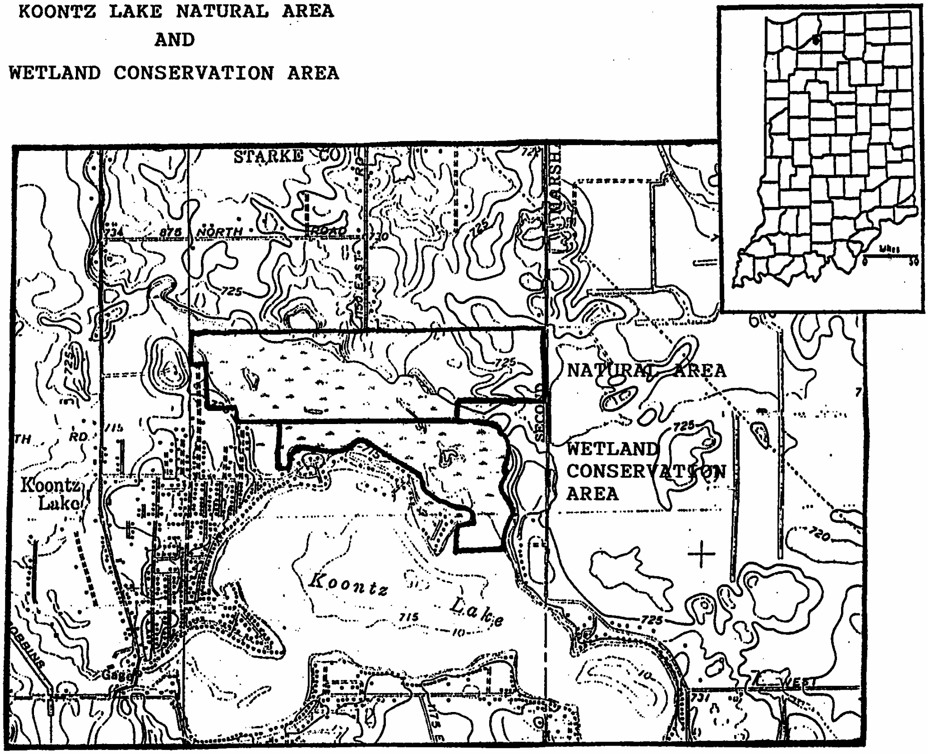


Figure 49.

PUBLIC ACCESS

KOONTZ LAKE NATURAL AREA
AND
WETLAND CONSERVATION AREA



Koontz Lake natural area is located just north of Koontz Lake in Starke County. Owned by the Indiana Department of Natural Resources, this 145 acre boreal forested marsh is home to a number of plants and animals rare, threatened or endangered in Indiana.

Tamarack trees, normally confined to the northern Great Lake states and Canada, are abundant in this natural area. Typified as a Leatherleaf marsh, other unique habitants include: high bush blueberry, Canada Mayflower, grape fern, Blanding's and spotted turtles.

The Wetland Conservation Area protects one of the primary inlets to Koontz Lake. Dominate vegetation includes cattail, sedges and button-bush. Wildlife species common to the area include deer, waterfowl, furbearers, pheasant and shorebirds.

LARGEMOUTH BASS POPULATION AT KOONTZ LAKE

Progress Report : 1987

Bob Robertson, Fisheries Biologist

METHODS

April 27 through May 26, electrofishing (D.C.) for largemouth bass was conducted one night per week for five weeks. Bass were picked up by two people with dip nets. Weekly sampling consisted of electrofishing eight randomly selected sections of shoreline for 15 minutes each. All bass collected were fin clipped and released. All marked bass collected during subsequent sampling were noted.

In September, the lake shoreline was electrofished two nights for a total of 180 minutes (six 15 minute stations each night) to collect largemouth bass including young-of-the-year.

RESULTS

A total of 1,044 largemouth bass were collected in 10 hours of electrofishing (104 bass per hour). Twenty-six bass were recaptures resulting in a population estimate of 16,537 bass (Table 1).

Table 1. Schnabel estimate of largemouth bass abundance at Koontz Lake, 1987.

Sampling Date	Number Captured	Marked at Large	Recaptured Bass	Schnabel Estimate	Standard Error
4/27/87	239	0	0	0	0
5/6/87	270	239	6	9,219	3,484.3
5/14/87	198	503	7	11,723	3,133.1
5/20/87	144	694	5	13,898	3,188.4
5/28/87	219	833	8	16,537	3,182.5
	1,070		26		

An additional 3 hours of electrofishing in September resulted in the collection of 609 largemouth bass (203 bass per hour). One hundred eleven of these fish were y-o-y ranging in length from 2.5 to 5.8 inches (Table 2).

Table 2. Yearly catches of young-of-the-year largemouth bass at Koontz Lake.

Year	1984	1985	1986	1987
Electrofishing effort	1.5 hrs.	1.5 hrs.	3.0 hrs.	3.0 hrs.
Number of y-o-y bass	30	2	201	111
Sampling date(s)	9/26	9/10	9/23,10/22	9/22,9/29

CONCLUSIONS

Of the 1,044 bass collected, only 8 (0.8%) were 14 inches or larger (Table 3). The large 1983 year class observed in 1985 and 1986 represented only 8.7% of the bass collected in 1987. Presently the 1984 year class appears strongest (Table 4). The number of bass continues to increase (Table 5).

Proportional Stock Density (PSD), the percentage of bass 8 inches and larger that are 12 inches and larger remains low at 7.9. Ideally, bass PSD's range from 40-60. Sub-legal size bass continue to dominate the population although the percentage of age IV+ and older bass increased from 5.2% in 1986 to 15.1% in 1987.

Submitted by: Bob Robertson, Fisheries Biologist
Date: 2/9/88

Approved by: Gary Hudson

Gary Hudson, Fisheries Supervisor

Date: 2/17/88

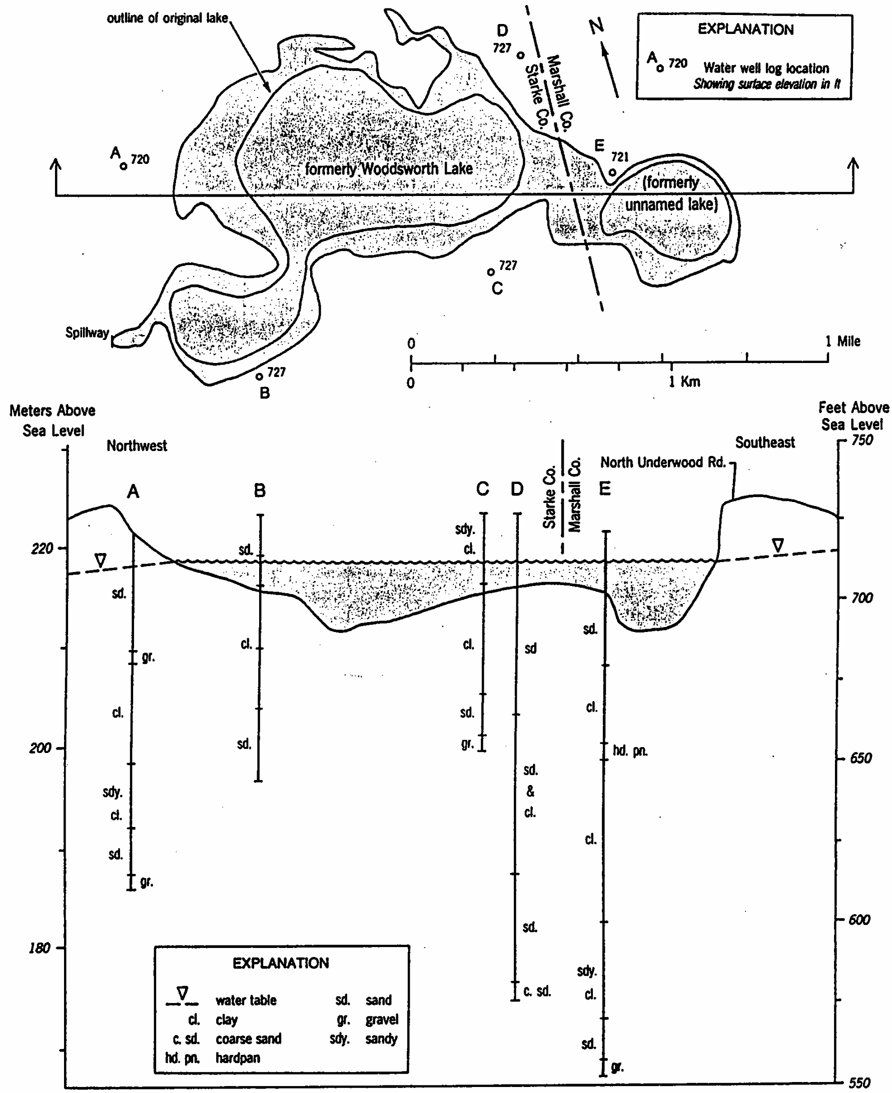


Figure 10. Aerial outline and profile of Koontz Lake showing surface- and ground-water level and logs of nearshore water wells. Datum is mean sea level.

Environmental Geologic Considerations in Koontz Lake, Starke County, Indiana, and Its 6-Mile Fringe

By EDWIN J. HARTKE

ENVIRONMENTAL STUDY 20

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY OCCASIONAL PAPER 51

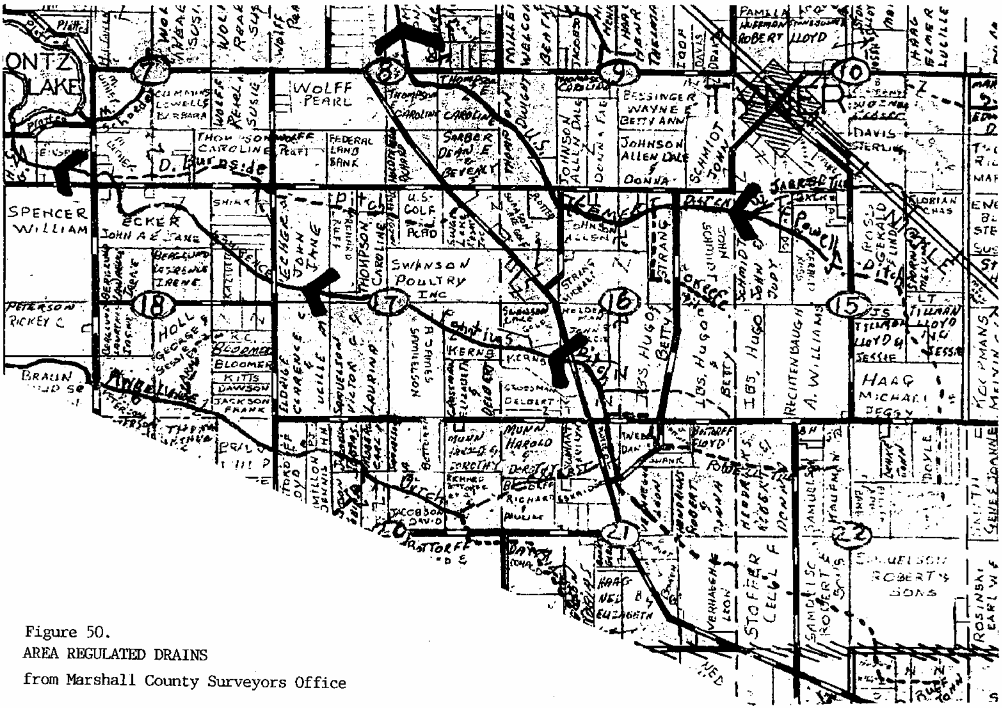


Figure 50.
AREA REGULATED DRAINS
from Marshall County Surveyors Office